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THESIS

THE ANALYSIS OF SOCIETAL WARFARE

by

Kevin G. Briggs

March 1987

Thesis Advisor James G. Taylor

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This thesis develops an adaptive structure for analyzing problems involving sociotechnical systems in the context of societal warfare. The structure, called the Modular Analysis Process (MAP), has been designed to help solve problems that require policy and/or systems analysis approaches to evaluate. The MAP can be used to analyze the impact of alternative designs on a complex system's architecture, (say, to its doctrines, machines, procedures, organizational structure, etcetera), in relationship to a scenario and mission. The MAP helps the analyst to efficiently develop cost-effective solutions to problems.

Most of this thesis' examples pertain either to the area of command and control (C2) above the theater command level or to strategic C2.

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The Analysis of Societal Warfare

by

Kevin G. Briggs
Captain, United States Air Force
B.S., United States Air Force Academy, 1979

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY
(Command, Control and Communications)

from the

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March 1987

ABSTRACT

This thesis develops an adaptive structure for analyzing problems involving sociotechnical systems in the context of societal warfare. The structure, called the Modular Analysis Process (MAP), has been designed to help solve problems that require policy and/or systems analysis approaches to evaluate. The MAP can be used to analyze the impact of alternative designs on a complex system's architecture, (say, to its doctrines, machines, procedures, organizational structure, etcetera), in relationship to a scenario and mission. The MAP helps the analyst to efficiently develop cost-effective solutions to problems.

Most of this thesis' examples pertain either to the area of command and control (C2) above the theater command level or to strategic C2.

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TABLE OF CONTENTS

I. INTRODUCTION 10
  A. PURPOSE AND ACKNOWLEDGEMENTS 10
  B. SCOPE 12
  C. GOALS FOR THE ANALYSIS STRUCTURE 15
  D. STRUCTURE OF THESIS 16
  E. CHAPTER SUMMARY 16

II. DEFINITIONS 19
  A. CHAPTER OVERVIEW 19
  B. SOCIETAL WARFARE 19
    1. Societal Warfare Defined 19
    2. The Soviet View of Class Struggle, Peaceful Coexistence and War 20
  C. SOCIOTECHNICAL SYSTEMS (SS) 22
    1. Section Overview 22
    2. Sociotechnical Systems Defined 22
    3. System Architecture 25
    4. System Entities 26
    5. The System Structures 32
    6. The System Processes 34
  D. CHAPTER SUMMARY 43

III. THE MODULAR ANALYSIS PROCESS 45
  A. CHAPTER OVERVIEW 45
  B. PROBLEM(S) 45
  C. PROBLEM FORMULATION AND CONTROL 47
    1. Problem Formulation and Control Management 47
    2. Determining the Analysis Objectives 49
    3. Characterizing the Problem 52
    4. Using Varying Analysis Perspectives to Bound the Problem 56

5. Formulating the Analysis Approach 60
6. Developing the Solution Management Plans 61
7. Completing an Initial Assessment 64

D. FORMULATING THE DESIRED STATES 64
1. Formulating Capability Objectives 65
2. Formulating Implementation and Political Objectives 66

E. FORMULATING SOLUTION ALTERNATIVES 67

F. FORMULATING THE SCENARIO 67

G. BUILDING CASES 69

H. DEVELOPING MEASURES 72
1. Section Overview 72
2. Effectiveness Measures 72
3. Implementation Measures 80
4. Political Measures 82
5. Selecting Measures 84

I. ASSESSING MEASURES 86
1. Section Overview and General Comments 86
2. The Quantitative Assessment Approach 87
3. Qualitative Assessment Approaches 89

J. ASSESSING ALTERNATIVES 89
1. General Remarks About Assessing Alternatives 90
2. Full Dimensionality Techniques 91
3. Single Dimensionality Techniques 92
4. Intermediate Dimensionality Techniques 98
5. Conclusions Concerning Assessing Alternatives 100

K. RESULTS PRESENTATION 100
1. Presentation Objectives Determination 101
2. Audience Analysis 101
3. Presentation Development 103
4. Interim and Finished Presentations 104

L. CHAPTER SUMMARY 105

IV. THE GLOBAL SCALE WARFARE (SUPERCINC) C2 PROBLEM 106

A. CHAPTER OVERVIEW 106
B. DETERMINING THE ANALYSIS OBJECTIVES 106
  1. Identifying the Decision-Makers 106
  2. Identifying the Decision-Makers' Analysis Objectives 108
  3. Determining How the Analysis Should Support the Decision-Makers 110
C. FORMULATING AN ANALYSIS APPROACH 110
  1. The General Analysis Approach 110
  2. Assumptions about the SuperCINC Problem 111
  3. Selecting the Analysis Perspectives 112
  4. Previewing and Scoping the Remaining MAP Modules 113
D. CHAPTER SUMMARY 114

LIST OF REFERENCES 118

INITIAL DISTRIBUTION LIST 121

LIST OF TABLES

1. THE TRANSFORM OPERATOR ENTITY TYPES 29
2. SOURCES OF TRANSFORM LOGIC 31
3. IDENTIFYING THE DECISION-MAKER'S ANALYSIS OBJECTIVES 51
4. EXAMPLES OF ENTITY MEASURES 76
5. EXAMPLES OF ENTITY RELATIONSHIP MEASURES 77

LIST OF FIGURES

1.1 The Three Dimensions of Challenge in the MAP 14
2.1 The Basic Model of a System 24
2.2 The System Entities 27
2.3 Aspects of System Structure 33
2.4 An Overview of the System Processes 36
2.5 Heirarchical Transform Processes 38
2.6 The Seven Generic Functions 39
2.7 An Expansion of the Seven Generic Functions 40
3.1 The Modular Analysis Process 46
3.2 The Problem Formulation and Control Module 48
3.3 Determining the Analysis Objectives 50
3.4 An Expansion of a Problem's Three Challenges 53
3.5 Characterizing the Challenges in a Problem 55
3.6 Identifying and Bounding Systems 57
3.7 Solution Management Plans 62
3.8 Formulating the Desired States 65
3.9 The Case Building Module 70
3.10 The Global Measures Set 73
3.11 Effectiveness Measures 74
3.12 Process Measures 78
3.13 Examples of Implementation Measures 81
3.14 The Categories of Political Measures 82
3.15 Several Scorecards from the POLANO Project 99
3.16 The Results Presentation Module 102
4.1 The Problem Formulation and Control Module 107
4.2 Escalating War Scenario - Part I 115
4.3 Escalating War Scenario - Part II 115
4.4 Surprise Attack Scenario 116

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I also thank my friend, Patrick Gandee, for his helpful suggestions and lively discussions over many of the concepts presented herein.

Finally, I would like to express my gratitude to my fiancee, Laura Horton, for her support, encouragement and patience throughout the development of this thesis. Her faith helped to make me enjoy this Ecclesiastes 12:12 experience.

I. INTRODUCTION

> War is a matter of vital importance to the State; the province of life or death; the road to survival or ruin. It is mandatory that it be thoroughly studied.

- Sun Tzu (Date: Approximately 500 B.C.) [Ref. 1: p. 63]

A. PURPOSE AND ACKNOWLEDGEMENTS

This thesis develops an adaptive structure for analyzing problems involving complex sociotechnical systems[1] in the context of societal warfare.[2] It is a tool by which war, as Sun Tzu has exhorted, can "be thoroughly studied." Throughout the thesis, this adaptive analysis tool will be called the *modular analysis process* (MAP). It is hoped that the MAP will help in the efforts to efficiently study and effectively respond to the complex problems associated with societal warfare.

The MAP is an adaptive analysis tool for three principal reasons. First, it is adaptive in that it is built around analysis principles rather than a specific application or method. Principles transcend methods. That is, they are generally applicable to any analysis rather than being tailored to a specific type of problem. For example, when a software development team is in the initial stage of developing a complex computer program, they normally follow the principle of modeling the information flow and control within that program before actually beginning to code the program. The principle here is to decompose a complex program by modeling information flow and control at the onset. This decomposition can be done by numerous methods, such as flow charts, software verification diagrams, data flow diagrams, structure charts, etcetera. The difference is that a method is a specific means of implementing a principle.

---

[1] As defined by H. A. Linstone, the issues in a sociotechnical system "must deal not only with the technological aspect but with the social and human facets surrounding and interacting with it" [Ref. 2: p. 39].

[2] For the purposes of this thesis, "societal warfare" refers to the process whereby a nation or nation-group engages in actions along any dimension of the social conflict spectrum in order to dominate, control, weaken, or destroy an opposed nation or nation-group. The terms "societal warfare" and "sociotechnical systems" will be explained in more detail in the next chapter.

Second, the MAP is adaptive in that it is conforming. It can be shaped to fit the problem of interest. The structure explicitly allows for the uniqueness of a particular problem. It does this by allowing the analyst to select which portions of the MAP are applicable to the problem of interest. The analyst is not required to step through every module or concept within the structure.

A final reason that the MAP is an adaptive tool is because it encourages the analyst or analysis team to examine a problem from a variety of perspectives (that is, a Singerian[3] approach [Ref. 2: p. 16]. For example, when building an analysis team, the MAP encourages the enlistment of people with not only interdisciplinary backgrounds, but also ones with interparadigmatic backrounds, (that is, those who have different methods of inquiry and problem-resolution) [Ref. 2: p. 358]. A Singerian problem formulation would ask questions such as those listed below.

1. Has a broad enough perspective on the way to solve the problem been taken?
2. Is the right problem being solved?
3. What are the modes of inquiry that should be used for the analysis?

The MAP itself is an expansion and integration of some of the most current and/or popular systems and policy analysis methodologies. A complete list of the sources for these methodologies can be obtained by examining this thesis' references. The following paragraphs will briefly describe the principal works consulted.

The MAP structure has been influenced primarily by the following works: E. S. Quade's books entitled *Analysis for Public Decisions* and *Handbook of Systems Analysis*, H. A. Linstone's book titled *Multiple Perspectives for Decision Making*, R. Sweet's Modular Command and Control Evaluation Structure (MCES) as described in the publications entitled *Command and Control Evaluation Workshop* and *The Modular Command and Control Evaluation Structure (MCES) -- Applications of and Expansions to C3 Architectural Evaluation*, and T. P. Rona's paper, *C3 As a Force Multiplier.*

Edward Quade's works have helped primarily in identifying the major practices and pitfalls in the analysis of complex public policy and military problems. His works have served as a baseline for much of what follows in this thesis.

---

[3] According to H. Linstone, the Singerian mode of analysis is a pragmatic meta-inquiring system which includes application of other systems (such as Hegelian and Kantian) as needed. To gain an appreciation for the Singerian approach, Chapter 10 of the following book is useful: *Thought and Wisdom*, by Churchman, C. W., Intersystems Publications, Seaside, California, 1982. [Ref. 2: p. 15]

Harold Linstone's work has had its principal impact by highlighting the importance of analyzing complex sociotechnical systems from more than what he terms is the "technological" or "rational actor" perspective [Ref. 2: p. 5]. Linstone's work explicitly shows the importance of analyzing the decision-making components of complex sociotechnical systems from several perspectives, to include organizational and personal perspectives (this terminology will be further explained in chapter III of this thesis). In addition, he has helped to show the value of using multiple analysis perspectives throughout the analysis process.

Dr. Ricki Sweet's MCES has proved very helpful in the development of effectiveness evaluation methodologies. In particular, many of the ideas for this thesis originated at two workshops aimed at applying the MCES to Department of Defense (DoD) problems. The first of these workshops, sponsored by the Military Operations Research Society (MORS), sought to apply the MCES to a broad range of DoD problems. The second workshop sought to apply the MCES to some problem areas specified by the Strategic Defense Initiative Organization.

Thomas P. Rona's paper has helped in developing principles to decompose and describe complex systems. In addition, his works have proved very helpful in developing principles to evaluate system missions. The following paragraphs will expand upon the scope of this thesis' analysis structure.

B. SCOPE

The MAP is designed to help decision-makers and analysts develop effective and adaptive responses to problems that involve the interactions of opposed, complex sociotechnical systems. These are problems that require policy and/or systems analysis approaches to understand and evaluate. The MAP is helpful in that it provides a conceptual roadmap for how to relate and integrate the various activities required for analyzing complex, opposed systems.

Many of the concepts presented in this thesis are also found within the Soviet analysis works. It is beyond the scope of this thesis to examine these works other than to mention that a significant, substantive body of Soviet thought does address the issues of concern in this thesis.

The MAP can be used to help solve a broad range of problems. For example, this structure can be used to guide the analysis supporting the acquisition or modification of major systems within the various phases of the Planning, Programming, and Budgeting System (PPBS) [Ref. 3: p. 17], (for example, the concept definition, acquisition, and operational life-cycle phases). Yet the MAP is not limited to analysis in support of PPBS decisions. It can also be used to assess the merits and costs of organizational changes in response to threats. For example, it can be used to analyze the impacts of procedures, training, doctrines, and organizational structure in the contexts of scenarios and missions. A final example of how the MAP can be used is that it can help to develop correlation of forces assessments (alternately called "net assessment" by the Office of the Secretary of Defense (OSD)) between opposed complex sociotechnical systems to identify adverse trends and evaluate possible solutions.

The MAP explicitly looks at the three dimensions of challenge typically present with any problem involving societal warfare, namely, the external challenges (i.e., the nature of the threat), the support challenges (i.e., the various factors that limit the options for addressing an external threat), and the leadership challenges (i.e., solution management). These three challenges are illustrated in Figure 1.1 . An example of each of these challenges will be provided in the following paragraphs.

An example of an external challenge or threat would be a trend where deterrence is weakened because a potential enemy is increasing its strategic Sea Launched Ballistic Missile (SLBM) and Intercontinental Ballistic Missile (ICBM) force capabilities. This external challenge results in an imbalance that, for the purposes of this example, will require special action on the part of the hypothetical opponent to rebalance. This special action could take on many forms, such as initiating studies to determine the impacts of the changing threat to allied forces and their command and control (C2).

With every external challenge, there is an associated set of support challenges, that is, the various challenges associated with gaining support to counter a perceived threat. If, for example, a strengthening of deterrence is sought through the development of a strategic defensive system, then a vast array of allied support challenges might arise, such as those involving technological support, fiscal support, public support, international support, etcetera. The extent to which support can be obtained defines the limits that the analyst and decision-maker must work within.

The challenge of managing the development of a solution that considers and effectively responds to the above two challenges is the final dimension of challenge in the MAP, namely, the leadership challenge. The MAP has been designed to provide a managerial framework for developing these adaptive responses. Hence, the MAP not

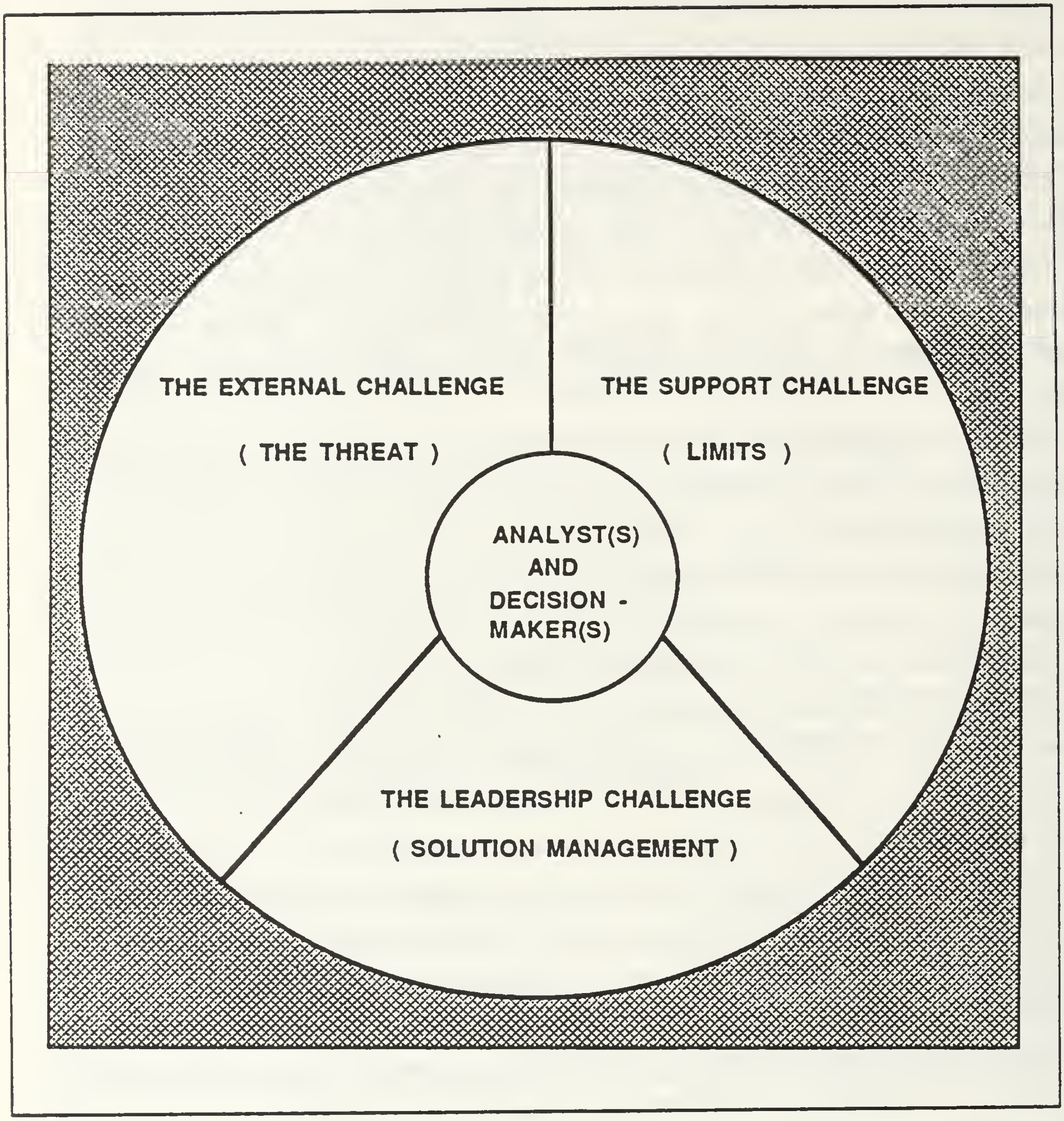

Figure 1.1 The Three Dimensions of Challenge in the MAP

only seeks to guide the analyst into developing cost-effective solutions to a decision-maker's problem, it also helps the analyst to effectively conduct the analysis.

Most of the examples used in this thesis will be taken from the areas of nuclear warfare analysis and command and control (C2) analysis. For example, the MAP will highlight some of the ways the United States' analysis community currently assesses strategic nuclear issues. In particular, the MAP will look at an extended example which examines the problem of how to design a command and control concept for the exercise of operational command[4] authority above the theater level commander in the context of multi-theater or global-scale warfare. This problem will be called the SuperCINC problem throughout the remainder of this thesis.

C. GOALS FOR THE ANALYSIS STRUCTURE

> The history of failure in war can be summed up in two words: Too Late. Too late in comprehending the deadly purpose of a potential enemy; too late in realizing the mortal danger; too late in preparedness; too late in uniting all possible forces for resistance; too late in standing with one's friends.

- General Douglas MacArthur [Ref. 4: p. 1]

There is one overriding goal behind the development of this analysis structure. This goal, which is alluded to in the above quote, is to help the analysis community discover and effectively counter adverse societal warfare trends before it becomes "too late" to stop these trends. This thesis' MAP can help to achieve this goal in the following two ways.

First, the MAP can help to counter adverse societal warfare trends by decreasing the amount of time required to conduct an effective analysis. This reduction in time can be achieved through the MAP in two ways. First, the MAP helps provide several definitions, such as the one for complex sociotechnical systems, that help the analyst to relatively rapidly conceptualize and decompose a problem. Thus, the structure helps to speed up the time required to answer the question of "what is the nature of the problem to be solved?" Second, the thesis provides a generic analysis process with which to solve problems. This MAP can be quickly adapted to the needs of a particular analysis and hence reduces the time required to develop an analysis methodology.

Whereas the previous paragraph has explained some ways in which the MAP can help with the efficiency of an analysis, three ways will now be examined that look at how the MAP can improve the effectiveness of an analysis. To begin with, the MAP can improve the effectiveness of an analysis by providing a structure that would stimulate, rather than constrain, the creativity and competence of the analyst. Many of the modules (to be described in subsequent chapters) of the analysis structure were designed explicitly to help achieve this goal.

---

[4] Operational command refers to those functions of command involving the composition of subordinate forces, the assignment of tasks, the designation of objectives and the authoritative direction necessary to accomplish the mission.

A second way the MAP can improve the effectiveness of an analysis is by its emphasis on improving the communications between the decision-maker(s) and analyst(s) throughout each stage of an analysis. The structure of the MAP will provide many tools to accomplish this goal.

A final way the MAP can improve the effectiveness of an analysis is by helping analysts develop solutions that avoid catastrophic errors. That is, special attention is given to highlighting how to implement stages of the structure in such a way as to avoid pitfalls in the analysis process.

D. STRUCTURE OF THESIS

This thesis has three major remaining sections. The first section, found in Chapter II, will develop the definitions to be used throughout the remainder of the thesis. In particular, the definitions for "societal warfare" and "sociotechnical system" will be developed. The term "sociotechnical system" will then be further decomposed into two major divisions: one describing structure and the other describing processes. The chapter will then develop the definitions for each of the constituent parts of these divisions.

The second major remaining section, found in Chapter III, will develop and explain the Modular Analysis Process (MAP). Each module will be briefly explained in the context of the analysis process.

The third and final major section of this thesis will use the definitions from Chapter II and the modules from the MAP developed in Chapter III to examine the SuperCINC problem (see the Scope section of this Introduction for a brief description of the SuperCINC problem). This chapter will lay the groundwork for future research into this problem and is only intended to demonstrate the utility of some of the modules within the MAP.

E. CHAPTER SUMMARY

This introductory chapter has provided an overview of the purposes, scope, goals, and structure of the thesis. Some of the key points of each of these sections of the introduction are summarized below.

The purpose of this thesis was stated as follows: to develop an adaptive structure for analyzing problems involving complex sociotechnical systems in the context of societal warfare. This structure, called the Modularized Analysis Process (MAP), is adaptive for three reasons. First, it is adaptive in that it is built on analysis principles rather than on specific methods. A second reason it is adaptive is because the MAP is conforming, that is, it can be shaped to fit the problem of interest. Third, it is adaptive in that it encourages the analysis team to view the problem from several different analytic perspectives.

The MAP was described as an integration and synthesis of some of the most current and/or popular system and policy analysis methodolgies. The key authors cited in this thesis are E. S. Quade, H. L. Linstone, T. P. Rona, and R. Sweet.

The scope of this thesis was explained as follows. First, the thesis is designed to help decision-makers and analysts address problems that require policy and/or systems analysis approaches to understand and evaluate. The MAP can be used to solve a broad range of problems. For example, it can be used to guide the analysis supporting the acquisition or modification of major systems within the various phases of the Planning, Programming, and Budgeting System (PPBS) process. It can also be used to assess the impacts of procedures, doctrines, and organizational structure in the contexts of scenarios and missions.

A second major aspect of the scope of this thesis is that the MAP considers three dimensions of challenge with every societal warfare problem. These three dimensions of challenge are illustrated in Figure 1.1 and are listed below:

1. the external challenge (that is, the threat),
2. the support challenge (that is, limits), and
3. the leadership challenge (that is, solution management).

The goals of the thesis were described as being to help improve the effectiveness and efficiency of an analysis. Several ways were mentioned that these goals would be realized. For example, the MAP can reduce the time required to perform an analysis by helping to provide several definitions, (such as the ones for sociotechnical systems to be developed in the next chapter), that help the analyst(s) to relatively rapidly conceptualize and decompose a problem. A second way the MAP can be used as a tool to more effectively perform an analysis is by providing a structure that helps to improve the communication between the decision-maker(s) and analyst(s).

The last section of the introductory chapter explained the structure of the remaining thesis. This structure has three major sections. The first section develops the definitions of the terms "sociotechnical system" and "societal warfare." In particular, the term "sociotechnical system" will be decomposed into two major divisions: one describing the system's structure and one describing the processes interacting with and in the system. Both divisions will be explained in detail. The second major remaining section of the thesis will develop the generic structure of the Modular Analysis Process (MAP). The final section will then apply portions of the MAP to an extended example called the SuperCINC problem.

II. DEFINITIONS

A. CHAPTER OVERVIEW

This chapter will provide a core of definitions that will be used throughout the remainder of this thesis. The chapter begins with a development of the term "societal warfare." The reason the chapter starts here is because this thesis' analysis structure, the Modular Analysis Process (MAP), is designed to examine complex sociotechnical systems in the context of societal warfare. This section will show that "societal warfare," for the purposes of this thesis, is more than just armed conflict between opposed nations. The Soviet's concepts of class struggle and warfare will be used to illustrate this thesis' use of the term "societal warfare."

The second major section in this definitional chapter explains the term "sociotechnical system." This term will then be decomposed into two major divisions: one describing structure and the other describing processes. These two divisions will then be further decomposed into their constituent parts.

B. SOCIETAL WARFARE

1. Societal Warfare Defined

> The first, the supreme, the most far-reaching act of judgment that the statesman and commander have to make is to establish . . . the kind of war on which they are embarking; neither mistaking it for, nor trying to turn it into, something that is alien to its nature. This is the first of all strategic questions and the most comprehensive.

- Karl von Clausewitz [Ref. 5: p. 1]

War is a societal process, not just a military endeavor. The outbreak of armed conflict between opposed military forces is merely one manifestation of this warfare, and often occurs at the end, rather than the beginning of a long struggle between nations. Those nations that become complacent during times of detente, or "peaceful coexistence" as the Soviet's might say [Ref. 6: p. 184], may too late discover that their self-proclaimed enemy has continued to wage an insidious, vigorous, and lethal form of societal warfare. Hence, throughout this thesis, the term "societal warfare" will mean the process where a nation and/or nation-group engages in overt and/or covert actions along any dimension of the social conflict spectrum in order to dominate, control, weaken, or destroy an opposed nation and/or nation-group.

The reason that the term "societal warfare" was selected, as opposed to the parallel Soviet concept embraced in their term, struggle, is because the term "warfare" invokes a higher level of response in the hearts of most hearers [Ref. 7: p. 38]. Soviet terms like "conflict" and "struggle" frequently do not generate much attention or rational fear in the minds of those who are the object of planned destruction or domination.

2. The Soviet View of Class Struggle, Peaceful Coexistence and War

This subsection will use the Soviet concepts of class struggle, peaceful coexistence, and war to help explain this thesis' use of the term societal warfare. This subsection will use several extended quotes to illustrate or explain the Soviet point of view.

The idea of class struggle (or in the terminology of this thesis, societal warfare), is a major tenet in Marxist-Leninist philosophy. The Soviets use terms such as "peaceful coexistence" and "struggle" in a way that diverges from the generally accepted Western connotation of these terms. For example, the Western usage of the term "struggle" does not require an unending struggle until the extinction of one social system (for example, Capitalism) whereas the Soviet sense of this word does [Ref. 7: p. 38]. These terms are somewhat soothing and subtle, and hence, can be used to weaken internal and external opposition to the vigorous form of societal warfare waged during the absence of armed conflict. For instance, as the book titled *Lexicon of Soviet Political Terms* states:[5]

> What the phrase PEACEFUL COEXISTENCE seems to imply is the recognition of the right of nations to decide their own destiny independently and to have their sovereignty and territorial integrity respected by other nations. Yet Lenin regarded PEACEFUL COEXISTENCE as a major form of class struggle. (Emphasis present in original text). [Ref. 6: p. 183]

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[5] This book is not a Soviet publication. It's author, Ilya Zemstov, was born in Baku, Russia and lived there until 1973. He received a Ph.D. in philosophy and a Ph.D. in sociology from the National Academy of Sciences in Moscow. Dr. Zemstov served on the executive board of the Soviet Sociological Association as well as serving a term as the Director of the Sociological Information Center in Baku. Dr. Zemstov is currently the Director of the Israel Research Institute of Contemporary Society where he is continuing his research on the Soviet system, which he now opposes. [Ref. 6: From the cover of this book]

An example of the Soviet usage of the words "peaceful coexistence" and "class struggle" are provided in the following quote, taken from a book titled, *Selected Soviet Military Writings 1970 - 1975.*

> The struggle to assert the principles of peaceful coexistence and mutually advantageous cooperation in relations between states with different social systems does not mean, of course, the relaxation or cessation of the class struggle between socialism and capitalism, the disappearance of the opposition between them, or a change in the social essence of these two social systems. The class struggle between socialism and capitalism is being waged and will continue in the economic and political fields as well as in the ideololgical field. We have been and remain opponents of imperialism, bourgeois ideology and morality. There has not been, there is not, and there cannot be a class peace between socialism and capitalism or peaceful coexistence between the communist and bourgeois ideologies. [Ref. 7: p. 38]

The Soviet concept of struggle during times of peaceful coexistence has allowed the Soviets to engage in a broad range of "struggles" against the West. Some examples of these would be the waging of ideological and psychological warfare against the West as well as justifying wars of liberation to weaken Western alliances [Ref. 6: p. 183]. The following quote illustrates the Soviet belief in engaging in class struggle at whatever level of conflict is best suited to the communist goals:

> Marxism is distinguished from all primitive forms of socialism by the fact that it does not tie the movement to any particular form of struggle. It recognizes the most varied forms of struggle . . . . At different moments of economic evolution, and depending upon varying political, national, cultural, and other social conditions, different forms of struggle assume prominence, become the chief forms of struggle, and in turn, cause the secondary and supplementary forms of struggle to change their appearance.

- Lenin [Ref. 8: p. 286]

The Soviets have long felt that they had a clearer understanding of the importance of class struggle, especially during times of "peace", than had the capitalist states. Lenin's statement that the capitalists "will sell us the rope with which to hang them," graphically demonstrates the feeling that Lenin had about the naivity of the capitalist states. The following discussion on this quote of Lenin's is found in the *Lexicon of Soviet Political Terms* :

> Lenin used to stress the view that the capitalists of the whole world and their governments would close their eyes to reality in the race to capture the Soviet market, and would be deaf, dumb, and blind. He said they would grant credits that would enable the USSR to support Communist Parties in their own countries. By providing materials and technology which the USSR lacked, they

> would rebuild Soviet military industry which later would facilitate a Soviet victory over its suppliers. In other words, the Capitalist profiteers would commit suicide . . . . To all appearances, the policy of detente, including the establishment and expansion of economic ties between the USSR and Europe and the USA, the development of trade, and the granting of generous Western credits to the Soviet Union, all look like Lenin's rope: with the difference that instead of being hanged, the "capitalists" may now be killed by nuclear weapons systems they contributed to--directly or indirectly. [Ref. 6: p. 184]

Finally, the Soviet's view of the term "war" is explained in the following quote. Although this quote's use of the term "war" (as opposed to this thesis' use of the term societal warfare) is confined to armed conflict, it does place armed conflict into a fuller context, that of societal politics. This fuller context is also embodied within this thesis' term, societal warfare. This quote is taken from the book, *Selected Soviet Military Writings 1970 - 1975*, and is General of the Army V. G. Kulikov's comments on Marshal of the Soviet Union B. M. Shaposhnikov's book, *The Brain of the Army*.

> Based on the Leninist understanding of the nature of war as a continuation of politics by other--namely, forcible--means, the author convincingly shows that the substance of war cannot be reduced merely to a collision of opposing armed forces. He writes: "A war is waged by a state as a whole, not only by its armed forces, which have been rushed to the front . . . . It is impossible to place war within the confines of strategy alone as though it were the monopoly of the military, for war is a specific form of social relations and not just a struggle with weapon in hand . . ." [Ref. 9: p. 186]

C. SOCIOTECHNICAL SYSTEMS (SS)

1. Section Overview

The following sections of this definitional chapter are divided into five major parts. The first will generally describe the term "sociotechnical systems" (SS). The second section will then explain the term, *architecture* as used thoughout this thesis. The remaining three sections will explain the three components of a system, namely, the system's entities, structures, and processes.

2. Sociotechnical Systems Defined

The following paragraphs define the term "sociotechnical system" (SS) and represent a stylized synthesis and expansion of several systems analysis paradigms. The term, sociotechnical system, is adapted primarily from H. A. Linstone [Ref. 2: p. 39], yet has been used by other authors as well. This thesis' synthesis is stylized in that it does not reflect fully any of the paradigms presented in the works referenced in the first section of the introductory chapter. Rather, this synthesis has selected only portions of any single view. The purpose here is not to proliferate terms or confuse those familiar with a particular paradigm, but rather to present a sufficiently robust set of definitions to support the remainder of the concepts presented in this thesis.

For the purposes of this thesis, a system is defined as collections of entities within structures conducting processes that normally have a common purpose or goal, but as a minimum are able to be grouped under a common logical identifier and can be logically bound. A sociotechnical system is a subset of the generic term *system* and refers only to those systems that have as a minimum the following seven attributes.

1. An SS has at least one human decision-maker within the system.
2. The SS has at least one mission.
3. The SS's mission(s) must involve some interaction with at least one other sociotechnical system.
4. These systems must transform inputs (stimuli) into some form of outputs (effects) in order to fulfill a mission or missions.
5. The outputs to the sociotechnical system are variable in time and type.
6. A sociotechnical system has the capacity to change its internal transform logic[6] via transform operators[7] in order to fulfill its mission.
7. An SS's human transform operators have the capacity to act according to self-interest rather than according to a mission.

A sociotechnical system is differentiated from a Command and Control (C2) system or a Command, Control, and Communications (C3) system in that it includes structures not normally included in a C2 or C3 system. For instance, an SS could include weapons systems, political systems, and other systems without any weapons association at all.

Figure 2.1 shows a basic model of a system. Dr. Thomas P. Rona has titled this "One Truly Accurate (and General) Model..." [Ref. 10: p. 27]. This figure is useful in that it embodies the general definition of a system and will be used as the building framework for most of the following definitions. Dr. Rona, speaking about C3 systems, has provided the following useful definitions of "stimulus" and "effect" that can be applied to any SS.

> Anything which changes the state of the C3 system is called a stimulus, irrespective of its origin or its authenticity. Anything that conveys these changes to the outside is called an effect. Both stimuli and effects have interfaces with the *outside* world and with the world *internal* to the C3 portion we have chosen for study. [Ref. 10: p. 27]

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[6] The term "transform logic" will be defined later in this chapter.

[7] The term "transform operators" will also be defined later in this chapter.

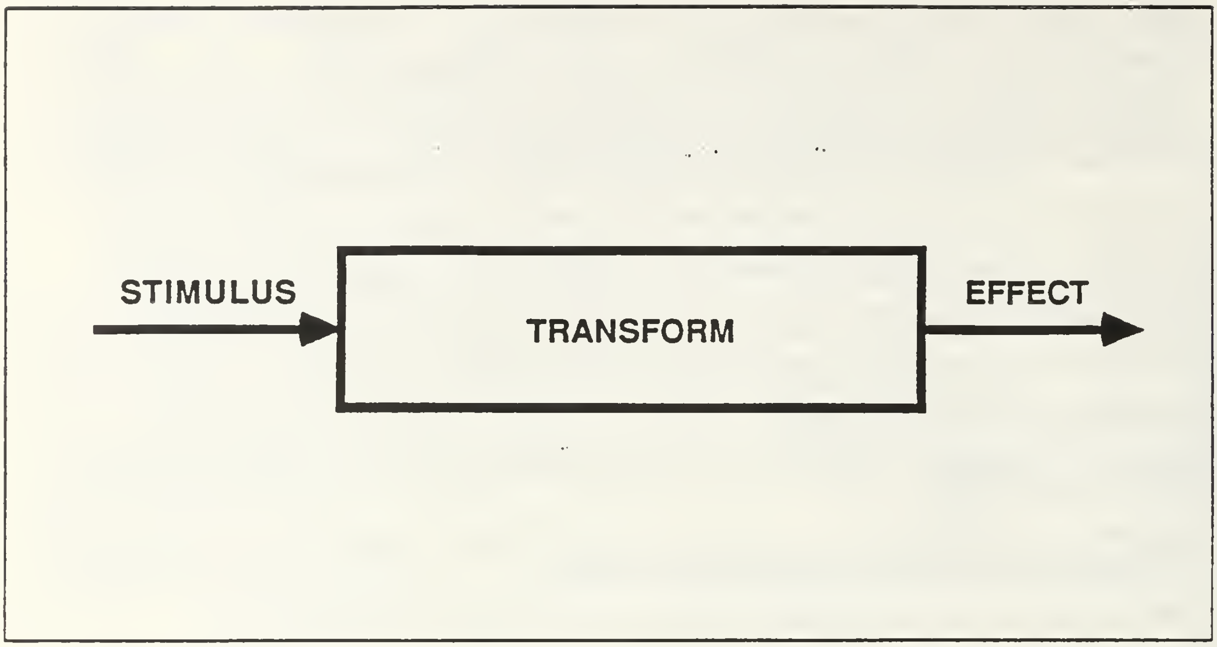

Figure 2.1 The Basic Model of a System

A concept that is parallel to that of stimuli is that of signals. Signals are different from stimuli in that a signal does not need to be be perceived by the system and hence it does not necessarily need to change the state of a system (i.e., the system of interest). A generic definition for signal is as follows. Signals refer to the set of all perceivable phenomena that occur that are potentially perceivable by the system.

Some additional definitions can be derived from Figure 2.1 . For example, the definition of the term "transform." For the purposes of this thesis, a transform will be defined as any process controlled by a transform operator that takes inputs (perceived stimuli) and changes them into outputs (effects). If the effect is only internal to the system, then only an "internal transform" has occurred. A "full transform" occurs only when the effect is conveyed outside of a bounded system.

A sociotechnical system can be described as having three principal components (although these components are not strictly mutually exclusive). These three components are system entities, structures, and processes. Before discussing these three system components however, an explanation of the term *architecture* as used within this thesis will prove helpful. This discussion follows in the next section. [Ref. 11: p. 2-3]

3. System Architecture

It is impossible for the human mind to consider every detail of a complex system all at once. Literally billions, if not an infinite number of elements, processes, etcetera, are existent within a system if this system is decomposed to its furthest extreme. Fortunately, for the purposes of most analyses, logical aggregations of elements, structures, and processes naturally occur within the system and enable the analyst to more easily comprehend the nature of a system.

Whereas the previous paragraph explained the need to aggregate from the infinite in order to be able to comprehend a system, the converse process is also required. A sociotechnical system's actions and reactions are typically too complex to understand and predict unless some level of system decomposition has been accomplished. Because of the finite nature of the human mind, (e.g., man can only think sequentially--one concept at a time), to understand the complex nature of systems requires some decomposition of these systems into manageable parts.

The first step in understanding complex systems is to develop architectures to represent these systems. An architecture,[8] for the purposes of this thesis, is a simplifying abstraction of the structure and/or processes either within or between existent or proposed sociotechnical systems. Architectures typically span several sociotechnical systems, but can also be confined to just one. Architectures do not necessarily need to be physically or visibly represented, although this is normally the case, but can also be logical constructs developed in one's own mind. Whatever form they take, the architectures must be some way of characterizing some aspect(s) of proposed or existent systems. Hence, an architecture is a vehicle where the results of decompositions and characterizations can be retained.

Architectures can take on many forms, but can be placed into three general categories: ones that represent physical and/or logical structures (for example, software structure diagrams, organization charts, floor plans, and wiring schematics) ones that represent processes (for example, software data flow diagrams, flow charts, and software system verification diagrams) and ones that integrate or coalesce structures with processes (for example, a system[9]verification with an associated functional allocation chart). For the purposes of this definitional chapter, only the nature of structures and the processes need to be examined. But before these will be examined, the next section will discuss the first component of a system, namely, the system's entities.

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[8] It is understood that there are numerous interpretations of the word architecture. For example, within the Defense Communications Agency a *systems architecture directorate* typically views systems at a higher level of abstraction than would an *systems engineering directorate*. Other usages of the word architecture include a "system of systems", a "roadmap for implementation", a "roadmap for analysis", and a "type of construction", to name a few.

4. System Entities

For the purposes of this thesis, the term *entities* refers to constructs (whether physical or logical) that have identity (i.e., distinct meaning) and can be bound by space or relational position. Figure 2.2 shows some of the types of entities that can exist.

Figure 2.2 shows that there are two principal classes of entities: those classified as to essence and those classified as their role. This figure further decomposes these class types as will be explained in the subsequent two subsections.

a. Entities Classified by Essence

Figure 2.2 shows that there are four primary types of entities that are classified by their essence.[10] These four types are listed below.

1. Inorganic
2. Logical
3. Organic
4. Hybrids

Inorganic entities are those that have physical identity and spatial bounding, but have no life. It is relatively simple to understand what may be considered an inorganic entity. Examples of these are machines, buildings, books, furniture, etcetera. It is a bit more difficult to see how logical constructs can also act as entities. The following paragraph will explain this type of entity in more detail.

Logical constructs are entities in that they can be associated and bound within space or a position (e.g., the position of the chief executive or commander) and can be identified as to type. For example, a readiness condition is a type of logical construct that could be bound by space, say, within the bounds of a military system. Another logical construct example would be one that involving authority. Authority can be identified as to type and it can be bound or reside within a given position. For

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[9] Michael S. Deutsch, in his book, *Software Verification and Validation*, provides some outstanding examples of how software verification diagrams with their associated functional allocation charts, can coalesce structures (i.e., software modules) and processes (to include input stimuli, transform processes, and output responses), as well as track requirements. [Ref. 12: pp. 18-22]

[10] Essence refers to the unchangeable aspects of the nature of an entity.

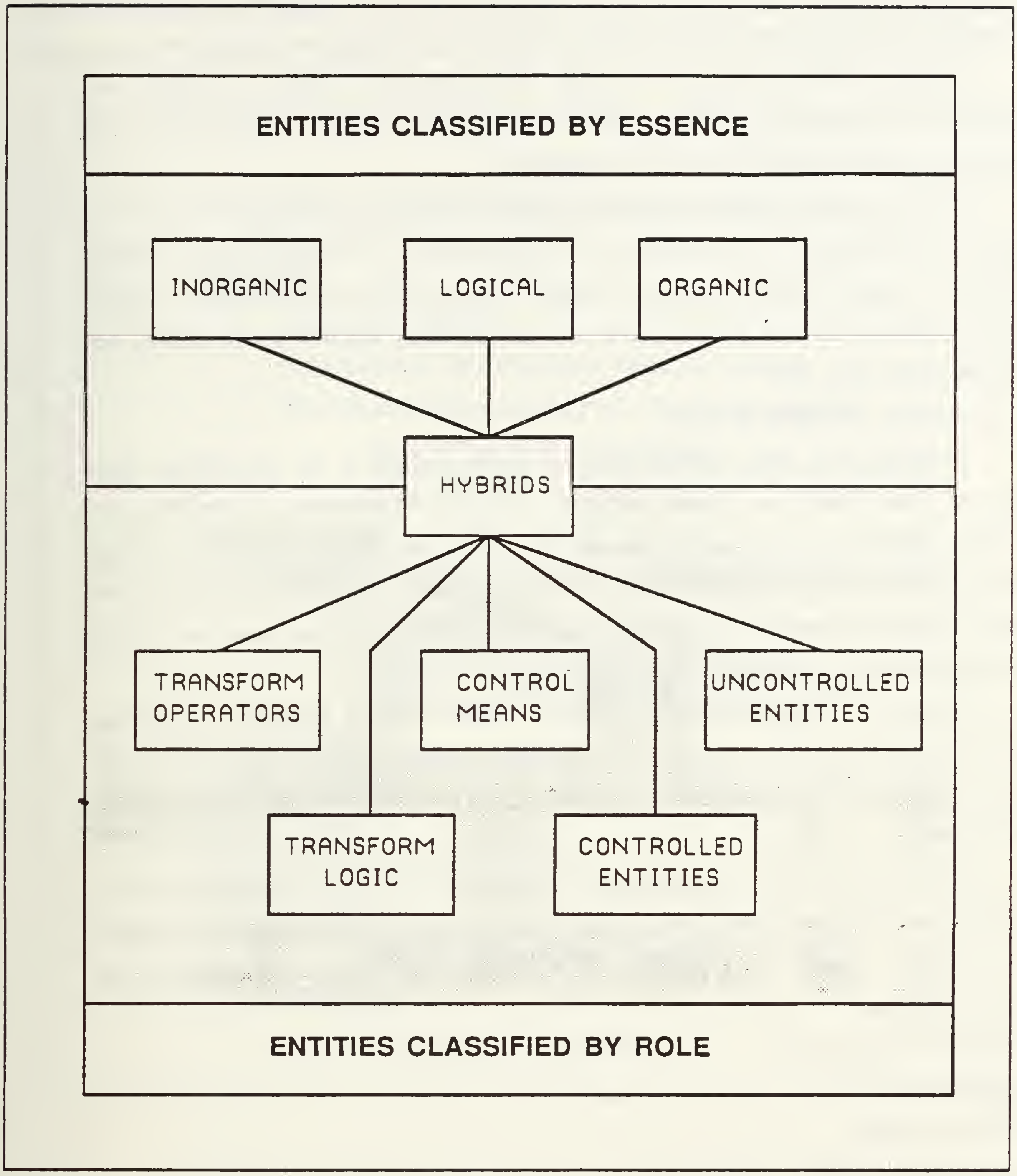

Figure 2.2 The System Entities

example, the authority to punish an offense may reside in the position of a squadron commander. It may also be described as residing in the individual who currently holds that position. A final example of a logical construct that is acting as an entity would be a rule of engagement. This entity may be bound within a geographic region, or within certain other entities within the system, such as an air defense missile battery.

Organic entities come in two types: human and non-human. Organic non-human entities are those that involve plants and animals. Human entities can be an individual, but can also include groups of humans.

The final type of entity was previously described as a hybrid of the previous entity types. An example of this would be an organization. An organization typically has inorganic, logical, human, etcetera entities coalesced into an integrated whole. These hybrid entities do not always have to contain every other type of entity, but must contain more than one.

b. Entities Classified by Role

Another way that entities can be distinguished is by classifying them according to their role (i.e., their purposes within a structure). This form of classification is typically much more temporal and multi-dimensioned than the previous classification by essence, because as will be shown, entities classified by function are dependent on scenario and because a single entity by essence can be classed according to numerous functions, sometimes all at once.

There are numerous ways a system's entities can be identified when their classification is based on their role. One role classification scheme that is relatively generic is illustrated in the lower half of Figure 2.2. This classification scheme will be discussed below.

For the purposes of this illustrative example, there are five primary types of role classifications that can distinguish entities when viewing a system from a paradigm based on control. These five types are listed below and will be discussed in the following paragraphs.

1. Transform Operators
2. Transform Logic
3. Control Means
4. Controlled Entities
5. Uncontrolled Entities

c. Transform Operator Entities

Transform operators, as illustrated in Table 1 , are the real-time and pre-real-time (PRT) decision-making systems (whether human, machine, or combinations thereof) that determine how stimuli (whether internal or external) should be handled and responded to. They are the adaptive agents that enliven the system's structure and processes. Hence, they control much of the activity within the system of interest.

TABLE 1
THE TRANSFORM OPERATOR ENTITY TYPES

- Individuals
  - Legitimate Leaders
  - Unappointed, but Popularly Selected Leaders
  - The Enemy Masquerading as a Legitimate Leader
    - Enemy Agents and Operatives
    - Enemy Ability to Supplant the Decision-Making of an Authorized Leader
- Small Groups and Organizations
  - Formal, Informal, and Illegitimate Decision-Making Cells
    - Advisory Groups
    - Special Interest Groups
    - Media and Propaganda Organizations
    - Executive, Legislative, and Judicial Groups
    - Military and Intelligence Organizations
- Social Classes
- Regional Groups
- Ethnic Groups
- Mechanical Transform Operators
  - Legitimate
    - Artificial Intelligence Systems
  - Illegitimate
    - Trojan Horses, etcetera

Transform operators typically take status information and coalesce this information with intuition to obtain an overall status (assuming a human transform operator and less than perfect or absolute status information). The transform operators then decide which decision criteria (embodied within the system's transform logic) should be applied to the decision(s) at hand. If these transform operators are human, then this decision will also be influenced by emotions, and other personal and/or group concerns.

Transform operators that are characterized as reflexive decisions systems do not require "real-time" cognition in the processing of the system stimuli. Rather, these operators could use pre-real-time (PRT) cognition that has been performed in anticipation of the arrival of certain stimuli. An example of a PRT transform operator would occur when the system's transform logic has been incarnated into the sociotechnical system via a hard-wired decision system. For example, a radar could be put in an automatic acquisition mode by a human whereby it could automatically decide which electromagnetic returns are valid candidates for tracking. Certain decisions that are made by humans could be called reflexive in that the humans are not making a decision requiring a lot of thought but are rather responding to an expected situation by implementing a decision that was previously made.

Transform operators can also take the form of real-time decision systems. These real-time transform operators can use the system's transform logic along with intuition, emotions, or combinations thereof to make "fresh" decisions, that is, ones that required more than a reflex response to stimuli. These real-time transform operators can also make decisions that are not in accordance with the system's transform logic. Table 1 provides a more complete list of the various forms that transform operators can take.

d. Transform Logic Entities

The transform logic entities are defined as the ideas that are present within a system transform operator or operators that act as the transform operator(s)' decision criteria. Transform logic can originate from many sources, some of which are shown in Table 2. The transform logic resident within given transform operators is often dormant or transient in that it may be activated only under certain circumstances and because at times it is passed to the entity as the need arises (e.g., an order from a higher authority). Table 2 provides a more complete list of the types of transform logic that may need to be considered in a sociotechnical system. [Ref. 10: p. 33]

e. Control Means Entities

Control means entities can take on many forms depending on the system of interest. Control means refer to the decision enforcement systems and the command and control (C2) systems that are used by a transform operator or operators to control other physical entities. These C2 systems perform the following seven generic functions for the transform operators. These seven functions will be discussed in more detail in the section in this chapter describing the system processes.

1. Sensing Functions

TABLE 2
SOURCES OF TRANSFORM LOGIC

World Views, Religions, and Philosophy
Laws of Society, Organizations, and Nature
Policy and Doctrines
Strategy, Operational Art, and Tactics
Concepts of Operations
Commands, Directives, and Procedures
Intuition
Paradigms
Training
Reflexes
Plans, Goals, and Desires
Principles and Precedence
Etcetera

2. Preparing Functions
3. Assessing Functions
4. Generating Options Functions
5. Decision Selection Support Functions
6. Planning Functions
7. Direction Functions

f. Controlled and Uncontrolled Entities

Controlled entities are simply the entities that are controlled by the system's transform operators. These controlled entities could take the form of weapons systems, resources such as money, subordinate transform operators, etcetera.

Uncontrolled entities are those that reside within the system of interest but are not controlled by any of the system's transform operators. These entities could include natural resources, animals, or those that exist as a result of enemy actions. An example of the latter would be a plasma region that would exist after a high altitude nuclear explosion within the upper atmosphere. These uncontrolled entities are typically very dependent on scenario and are often very transient in duration.

5. The System Structures

a. An Overview of System Structure

For the purposes of this thesis, a system's structure is defined as the set of all entities and entity relationships existent or possible within the bounds of scenario. Scenario, as used here, is defined as the set of missions, conditions, and events that are specified to occur or that could occur occur within or between the sociotechnical system(s) of primary interest and selected hostile, allied, and neutral interaction systems. The following sections will further define system structure and will examine the aspects of this structure.

b. Types of Structures

This thesis makes a distinction between three different types of system structure. These are: benign system structure, stressed system structure, and specific system structure.

Benign system structure is defined as the set of all possible entities and entity relationships that could exist sometime during the range of selected benign scenarios. Benign scenarios are defined as scenarios that are independent of any hostile events from opposed sociotechnical systems.

Stressed system structure is defined as the set of all possible entities and entity relationships that could exist sometime during the range of selected opposed scenarios. Opposed scenarios are defined as scenarios that contain hostile events from opposed sociotechnical systems.

Specific system structure is defined as the subset of benign or stressed system structure that is selected to exist at a given point in time within a scenario.

c. The Aspects of System Structure

For the purposes of this thesis, a system's structure is described by two major aspects: entities and entity relationships. These two aspects are illustrated in Figure 2.3. The first aspect was already discussed in the previous section, that of system entities. The following paragraphs will examine the nature of the system's entity relationships.

d. Entity Relationships

There are three major categories of entity relationships. These are ones that involve relationships internal to the parent sociotechnical system, ones that

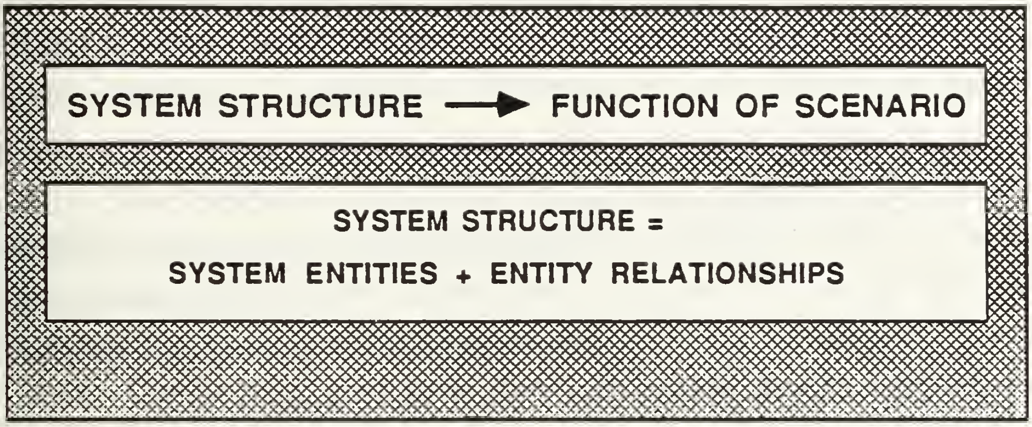
SYSTEM STRUCTURE ⟶ FUNCTION OF SCENARIO
SYSTEM STRUCTURE =
SYSTEM ENTITIES + ENTITY RELATIONSHIPS

Figure 2.3 Aspects of System Structure

involve relationships to external sociotechnical systems, and ones that involve relationships to the physical environment.

The first major category of entity relationships that will be examined involve relationships internal to the system of primary interest. These relationships include spatial relationships and state relationships. Each of these will be discussed in the following paragraphs.

Internal spatial relationships are those that refer to any relationships between entities within the parent system that involve distance, physical configuration, etcetera. These relationships could be described in terms of how far apart two entities, say two command nodes, are.

Internal state relationships involve two primary types:

1. the relationship of an entity to itself, and;
2. the relationship of an entity to other entities.

The state relationship of an entity to itself refers to the state or condition of the entity at a given point in time. Some examples of this type of relationship would be a a machine being either on or off, a door or window being opened or closed, a person being awake or asleep, etcetera.

Logical entities can also have state relationships to themselves. For example, a readiness condition can be at one of several levels or a rule of engagement can either in effect or awaiting activation.

The second major type of state relationship was described as refering to the relationship of an entity to other entities. State relationships between entities would include such things as authority and responsibility structures. In addition, state relationships could be stated in terms like hostile, neutral, cooperative, and combinations thereof between entities.

The second major category of entity relationships are those that involve external sociotechnical systems. These include relationships with hostile, neutral, and allied or friendly sociotechnical systems. Like the previous category, these relationships can also be classified as to either spatial relationships or state relationships. Some examples of spatial relationships between internal system entities and external systems would be the location of an aircraft to the enemy's radar system or the distance of a command center from an enemy's border. An example of a state relationship between an internal system entity and an external system would be whether a system entity, say a radar, was tracking an enemy's system entity, say an aircraft.

The last major category of entity relationships occurs between system entities and the external physical environment. These are also relationships that can be classified as either being spatial or state related. An example of a spatial relationship would be the geographic location of an entity. An example of a state relationship would be the temperature or weather conditions at the entity's location.

6. The System Processes

a. Section Introduction

This introduction will define this thesis' use of the term *system processes*, and will then overview what will be covered in the following subsections on the specific types of system processes.

The system processes add the dynamic dimension to a system. In a sense, these processes give evidence to the system's life. In the most general case, and for the purposes of this thesis, a system process is defined as any action or activity that transforms (i.e., changes) the state of the system.

There are four major categories of system processes that will be developed in this thesis. Each of these occur within the sociotechnical system(s) of primary interest as the system structure changes based on such things as scenario, stimuli, transform operator decisions, and decision implementations. These categories are delineated by who or what initiates (or primarily controls) the process. These categories are illustrated in Figure 2.4 and are listed below.

1. Transform Processes
2. Allied Processes
3. Environmental Processes
4. Threat Processes

It is important to note that within these categories of processes there are two types. These two types are listed below:

1. Generic processes;
2. Specific processes.

Generic processes are those which are applicable to all sociotechnical systems. They do not require or imply any specific structure. Dr. Joel Lawson's Command and Control process model is an example of a generic representation of processes. The following subsection of this thesis will provide some examples of generic processes.

Specific processes are, as the name implies, system specific. That is, these processes either implicitly or explicitly assume some type and configuration of structure, whether rigidly defined or not. Specific processes are typically dependent on scenario and the current configuration and status of the structure of the system of interest.

b. Transform Processes

The first process to be considered here is that of the transform process. A transform process can be of two types. The first, a full transform process, refers to any process controlled by transform operators (guided by the SS's transform logic) that takes inputs (stimuli) and changes them into outputs (effects), where the inputs originate external to the system and the effects are directed out of the system(s) of interest.

The second type of transform process is called an internal transform process. An internal transform process is the same as a full transform process except that the inputs and outputs can originate or terminate within the system(s) of interest. These internal transform processes can alternately be called "intermediate transform processes."

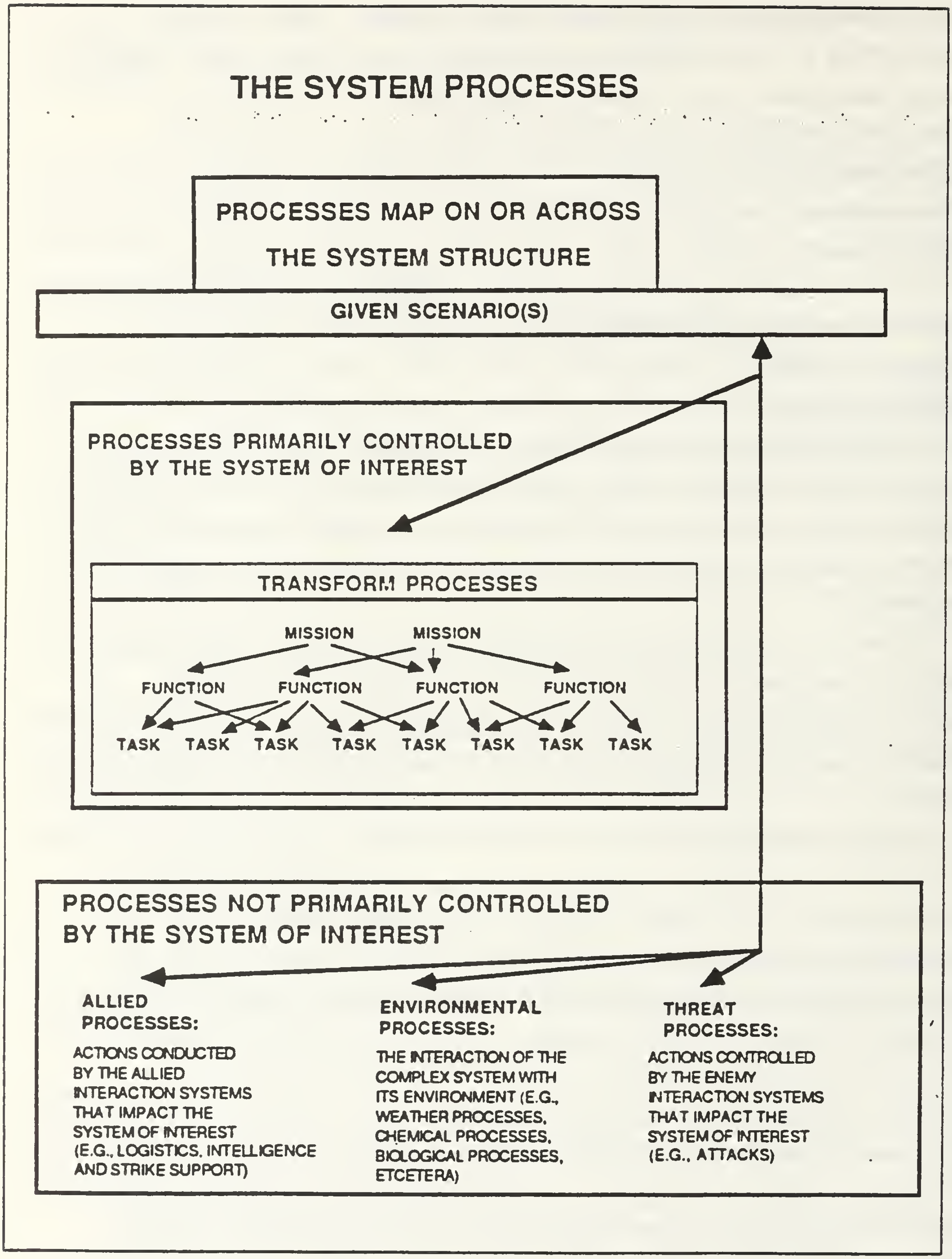
THE SYSTEM PROCESSES
PROCESSES MAP ON OR ACROSS THE SYSTEM STRUCTURE
GIVEN SCENARIO(S)
PROCESSES PRIMARILY CONTROLLED BY THE SYSTEM OF INTEREST
TRANSFORM PROCESSES
MISSION
MISSION
FUNCTION
FUNCTION
FUNCTION
FUNCTION
TASK
TASK
TASK
TASK
TASK
TASK
TASK
TASK
PROCESSES NOT PRIMARILY CONTROLLED BY THE SYSTEM OF INTEREST
ALLIED PROCESSES:
ACTIONS CONDUCTED BY THE ALLIED INTERACTION SYSTEMS THAT IMPACT THE SYSTEM OF INTEREST (E.G., LOGISTICS, INTELLIGENCE AND STRIKE SUPPORT)
ENVIRONMENTAL PROCESSES:
THE INTERACTION OF THE COMPLEX SYSTEM WITH ITS ENVIRONMENT (E.G., WEATHER PROCESSES, CHEMICAL PROCESSES, BIOLOGICAL PROCESSES, ETCETERA)
THREAT PROCESSES:
ACTIONS CONTROLLED BY THE ENEMY INTERACTION SYSTEMS THAT IMPACT THE SYSTEM OF INTEREST (E.G., ATTACKS)

Figure 2.4 An Overview of the System Processes

The responses or outputs of transform processes may be active (that is, observable) internally or externally to the system or it may be a passive response such as the adjusting of the status in the mind of a man acting in the capacity of a commander. Whether active or passive, the sociotechnical system must experience some change of state initiated by a transform operator before a transform process can be considered to have occurred.

A full transform process typically occurs when several internal transform processes have been linked together to perform a particular mission, function, or task. Each of these terms will be defined below and are graphically shown in Figure 2.5 . Note that this figure shows that functions and tasks (at whatever level) can be used to support more than one mission, function, etcetera. It is also important to note that the mission of, say, Complex System B, may merely be a function for a larger Complex System A of which B is a subset. [Ref. 13: p. 1-3]

A mission is a transform process that involves a broad area of endeavor taken on by a sociotechnical system of interest in relationship to another SS (or to itself as a whole) [Ref. 13: p. 1]. A mission must involve at least one full transform process, but may also encompass several additional full or intermediate transform processes.

An example of two missions would be the Strategic Air Command's (SAC's) missions of deterrence and escalation control in the context of nuclear war in relationship to other nuclear capable states. Here, the SS of interest is the SAC. The interaction systems are the targetted nuclear capable nations.

A function is defined as a transform process that is performed in order to achieve a major portion (or segment) of a sociotechnical system's mission(s)[11] [Ref. 13: p. 1]. A function can consist of either a full transform process or an intermediate transform process or combinations thereof. To follow through with the above example, a specific function that is a subset of SAC's mission of deterrence is that of the capacity to wage an assured Intercontinental Ballistic Missile (ICBM) attack against an opponent.

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[11] A good working example of how the terms mission, function, and tasks, can be defined and used in a data base exists in the *NCCS Ashore Data Base Users Manual*, prepared for the Commander, Space and Naval Warfare System Command, March 13, 1986.

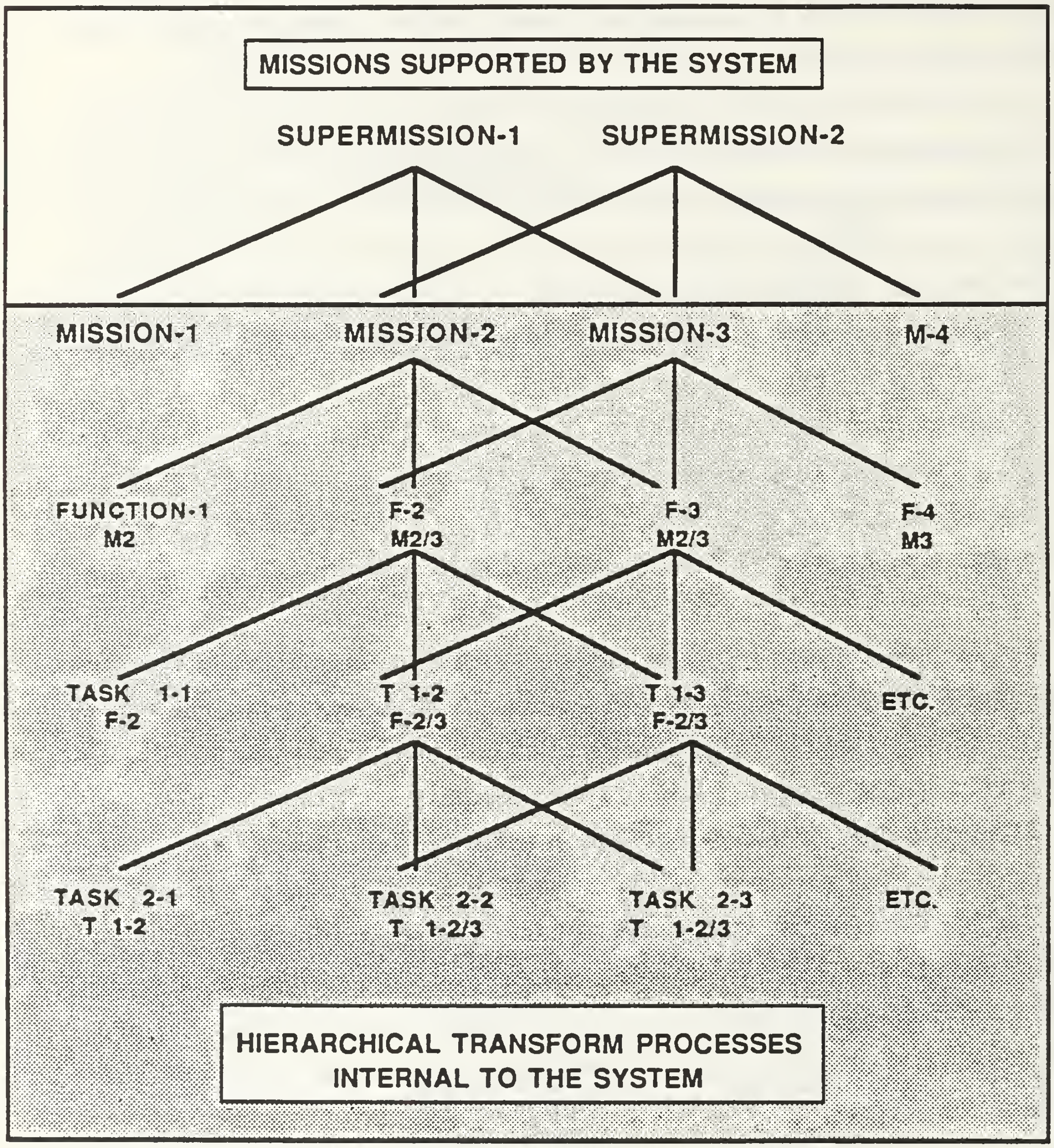


Figure 2.5 Heirarchical Transform Processes

Tasks are defined as transform processes that involve the groups of actions required to achieve some phase of a internal tranform function. Continuing the previous SAC example, an illustration of a task would be the capacity of a particular missile wing to support the overall function of being able to carry out an assured ICBM attack in order to support the SAC mission of deterrence. Tasks can be further broken down into various levels if the need arises.

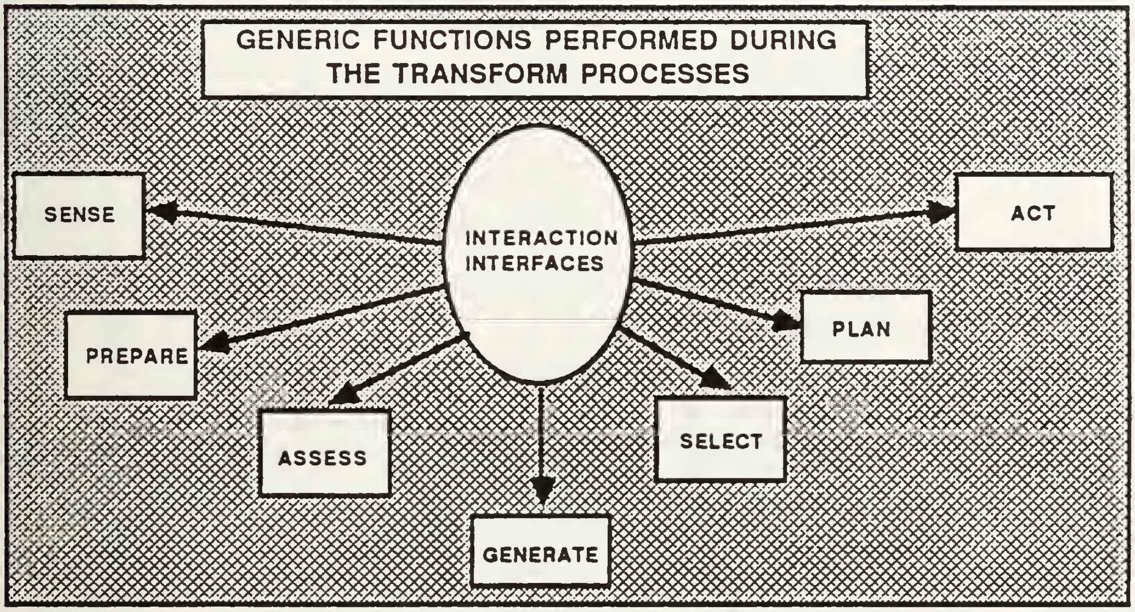


Figure 2.6 The Seven Generic Functions

Figure 2.6 and Figure 2.7 show that there are seven generic functions that are performed by all sociotechnical systems. It is not necessary that all of these

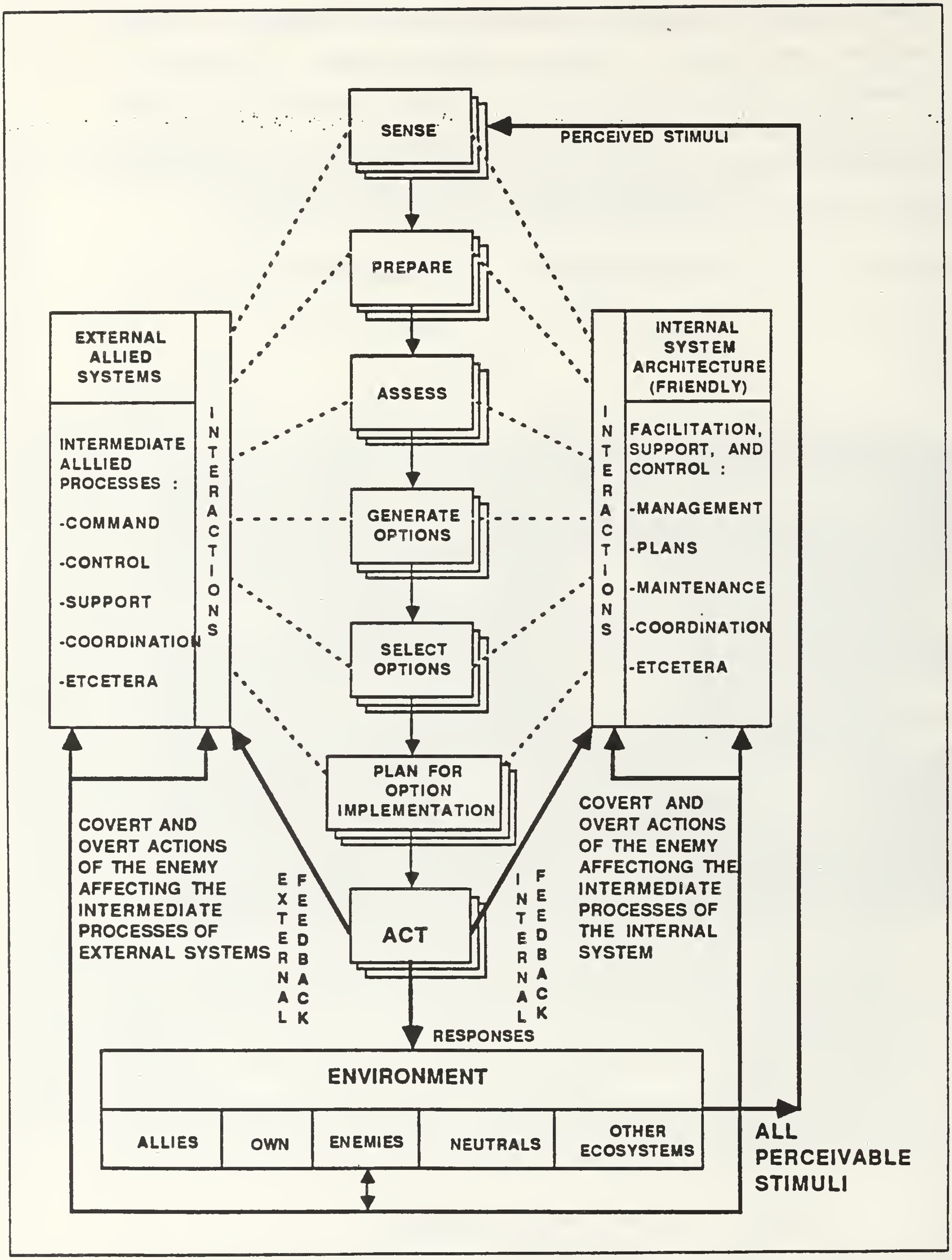

SENSE
PERCEIVED STIMULI
PREPARE
ASSESS
GENERATE OPTIONS
SELECT OPTIONS
PLAN FOR OPTION IMPLEMENTATION
ACT
EXTERNAL ALLIED SYSTEMS
INTERMEDIATE ALLLIED PROCESSES :
-COMMAND
-CONTROL
-SUPPORT
-COORDINATION
-ETCETERA
INTERACTIONS
INTERNAL SYSTEM ARCHITECTURE (FRIENDLY)
FACILITATION, SUPPORT, AND CONTROL :
-MANAGEMENT
-PLANS
-MAINTENANCE
-COORDINATION
-ETCETERA
INTERACTIONS
COVERT AND OVERT ACTIONS OF THE ENEMY AFFECTING THE INTERMEDIATE PROCESSES OF EXTERNAL SYSTEMS
EXTERNAL FEEDBACK
INTERNAL FEEDBACK
COVERT AND OVERT ACTIONS OF THE ENEMY AFFECTIONG THE INTERMEDIATE PROCESSES OF THE INTERNAL SYSTEM
RESPONSES
ENVIRONMENT
ALLIES
OWN
ENEMIES
NEUTRALS
OTHER ECOSYSTEMS
ALL PERCEIVABLE STIMULI

Figure 2.7 An Expansion of the Seven Generic Functions

functions be activated during a particular system mission. These functions are not necessarily sequential, but have strong sequential qualities. Figure 2.7 provides an expansion of the nature and context of the seven generic functions. This figure shows the many types of interaction systems and boundaries that occur between the SS of primary interest and the systems it interacts with. Specifically, the dotted lines in this figure show that the generic process is not necessarily sequential, but can iterate back and forth between blocks. In addition, these lines show that the stages of the generic process are perhaps suported by parallel interactions between allied external systems and the subsystems within the primary system of interest. Finally, this figure shows some of the places an enemy can interact with the primary system of interest and its allies. The darker arrows from the enemy show that the interactions can occur directly within the allied or primary system of interest, within the boundary prescribed between the allied or primary system's interactions, or outside of the primary system of interest, yet perceived by its sensors.

The seven generic functions are defined below and are adapted from several sources, most noteably, Dr. Joel S. Lawson [Ref. 14: p. 24].

1. Sense: Those processes which perceive stimuli (whether the stimuli is the reception of raw data, processed data, or information, or whether the stimuli is the perception of changes in physical states via electromagnetic sensors, etc.) internal and external to the sociotechnical system of interest and then transforms these stimuli through the agency of transform operators and their associated system architecture into an evolved form (that is, an internal response). One example of an evolved form would be the transformation of physical state stimuli into data. An example of a sensing function would be the transformation of electromagnetic waves into electrical data signals. The sensing processes can receive, restore, filter, aggregate, store, and route stimuli as part of its transformation process. The transformed stimuli (that is, effects or alternately, responses) that are collected are normally done so in order to be used by later functions in the evaluation of the internal and external environments.

2. Prepare: Those processes that take selected effects from other function(s), typically the sensing function, and then transforms these effects through the agency of transform operators and their associated system architecture into evolved forms that can be evaluated by other transform operator(s). In other words, this function receives and translates evolved forms of stimuli, and then stores, and/or forwards the effects as information about the internal and/or external environments in order to be understood by other system function(s). Information is here defined as stimuli that have been translated into a form that is intelligible to subsequent pertinent transform operators. An example of this function would occur when an electrical data signal was transformed into a printed symbol stream.

3. Assess: Those processes which take selected information provided by the other functions and then assigns comparitive meaning to this information through the agency of transform operators and their associated transform logic. This comparitive meaning is derived by comparing and evaluating inputs in the light of the system's plans, missions, goals, doctrines, etcetera. This meaningful information can take on many forms but always has a quality of providing the status of environments (for example, military systems) internal and external to the sociotechnical system of interest. In addition to assigning comparitive meaning to the received information, this function can store and route this

information to subsequent functions. An example of this function would occur when a group of printed symbol streams were interpreted by an intelligence analyst and published in the form a situation reporting message.

4. Generate: Those processes that take previously developed status information (as well as any other other information needed from the other function(s)) and then transforms this information through the agency of tranform operators and their associated system architecture into an option or options for use by subsequent functions.
5. Select: Those processes that take the option or options provided by the generate functions and then transforms these through the agency of the transform operators and their associated system architecture (particularly the transform logic) into the selection of courses of action. Options may be selected, non-selected and discarded, or non-selected and retained for possible future application.
6. Plan: Those processes that transform the outputs (for example, a selected option) of previous functions (through the agency of transform operators and their associated system architecture) into implementable plans.
7. Act: Those processes that translate implementable plans into actions through the agency of transform operators and their associated system architecture.

c. Allied Processes

Allied processes are defined as those actions that impact the primary system of interest that are either initiated by external sociotechnical systems that are friendly to this primary system or that are initiated by the sociotechnical system of interest but are carried out by the external friendly SS. Allied system processes can constrain, support, direct, etcetera, the primary system of interest. An example of an allied system process would occur when one country (the primary system of interest) is helped in its efforts to develop its military through the technical and economic assistance of an allied country (the external SS). Another example of an allied process, which could be viewed as a constraining process, would be a funding cut by the United States Congress (the allied system) of the Air Force's (the primary system of interest) MX ballistic missile system. A final example of an allied system process would be the intelligence and and logistics support provided to the primary system of interest (for example, a battalion) by an external superior system (say, a corps). This last example shows that the "external" system can actually have the primary system of interest as one of its subsets. An "allied" system can have either a superior, subordinate, or peer relationship to the primary system of interest.

d. Environmental Processes

An Environmental process is defined as any action that occurs that impacts the primary system(s) of interest that results from the natural interaction of the primary system(s) with the physical environment. These interactions can be brought about by weather, the passage of time, and any other ecosystem phenomena that may impact the system of interest given a scenario and mission (for example, ionospheric conditions, terrain conditions, time of day, resource availability, etcetera).

e. *Threat Processes*

Threat processes are defined as any actions that are initiated by an enemy or enemies that impact the primary system(s) of interest. Threat processes can include actions that (1) physically disrupt or destroy a system, (2) psychologically coerce or influence a system, (3) overtly or covertly exploit a system as well as (4) those indirect measures that prompt other systems (even those systems that are supposed to be allies) into adversely interacting with the primary system(s) of interest.

D. CHAPTER SUMMARY

This chapter has provided the reader with definitions for the terms that will be used throughout the remainder of this thesis. These definitions, while not rigorous, are sufficiently robust to provide a foundation for the modular analysis process (MAP) to be presented in the next chapter. In particular, the concepts of societal warfare and sociotechnical systems were developed.

The first portion of this chapter defined the term "societal warfare." It stated that this term refers to the processes whereby a nation and/or nation-group engages in overt and/or covert actions along any dimension of the social conflict spectrum in order to dominate, control, weaken, or destroy an opposed nation and/or nation-group. This section then examined the Soviet's view of terms such as *struggle* and *warfare* to contrast this thesis' use of the term societal warfare. This section demonstrated that societal warfare was both a social as well as a technological process and that societal warfare included the more insidious forms of conflict such as psychological warfare during times of "peaceful coexistence."

This chapter then examined the term sociotechnical system (SS). Seven requirements were then listed for a system to qualify as a SS. In general, these requirements showed that the SS had at least some human decision orientation and that the system could adapt itself to help fulfill a mission that involved at least one additional SS. This section also showed that there are three primary components that make up a system, namely:

1. system entities,
2. system structure, and,
3. system processes.

The next section of this chapter expanded the concept of system entities. This section showed that entities could be classified according to their essence (i.e., their unchanging nature) or by their role (their purposes within a given scenario at a given point in time). Both of these categories were subsequently broken into sub-categories. Entities classified by essence were explained as having fallen into one of the following four types: inorganic, organic, logical, and integrated hybrids of the previous three. Entities classified by role were illustrated to fall into one of the following five categories, although numerous other purpose related decomposition schemes could have been used: transform operators entities, transform logic entities, control means entities, controlled entities, and uncontrolled entities.

The following section of this chapter then explained what the term *system structure* referred to. System structure was defined as the set of all entities and entity relationships existent or possible within the bounds of scenario. It was shown that system structure was the integration of system entities with entity relationships. It was also shown that a system's structure changed as processes occurred within the system of interest. The system's entities were explained to be spatially and state related to themselves as well as to other entities internal and external to the system.

The final section in this chapter explained the term, *system processes*. System processes were defined as any action or activity that change the state of the system. These processes add the dynamic dimension to the system of interest. Figure 2.4 summarized the main aspects of a system's processes. These processes were shown to have two principal divisions. The first involved processes that resulted from transform operators using the system's transform logic to make decisions. Examples of these transform processes were system missions, functions, and tasks. The second division of processes involved activities that impacted the principal system of interest but were not conducted by the system's transform operators using the system's transform logic. Examples of these types of processes were the impacts of enemy attacks and of allied support.

The system processes, like the system structure, were shown to be a dependent variable. These processes are a dependent variable in that the system's processes will change or adapt according to scenario and mission contexts.

The next chapter will explain this thesis' analysis structure, namely, *The Modular Analysis Process* (*MAP*). This chapter will build on many of the definitions developed in this present chapter and will show how some of these concepts can be applied.

III. THE MODULAR ANALYSIS PROCESS

A. CHAPTER OVERVIEW

This chapter provides an explanation of the Modular Analysis Process (MAP). The definitions developed in Chapter II of this thesis, particularly those found in the section titled "Sociotechnical Systems", provide a foundation for many of the concepts presented in this chapter. In addition, the "Scope" section of Chapter I of this thesis describes the types of problems and challenges that the MAP can be applied to.

The major activities within the MAP are identified within the seven levels of modules illustrated in Figure 3.1. The flow of activities within an analysis are generally from the top to the bottom of the MAP, but normally will require iterations back to the upper levels after some insight or learning has occurred at a lower level. Activities within modules occurring at the same level are often performed concurrently. Not all of the blocks of the MAP are required for every analysis; however, normally every level will need to be visited unless the activity and information within a particular level was provided by prior analysis.

The remainder of this chapter will describe each of the modules and terms illustrated in Figure 3.1. Each module will be examined from the viewpoint of the lead analyst.

B. PROBLEM(S)

> I have yet to see any problem, however complicated, which, when . . . looked at . . . the right way, did not become still more complicated [Ref. 15: p. 5].

"Problem(s)" as depicted in Figure 3.1 refer to areas of concern or responsibility for decision-makers. Portions of these problems may be of such a nature that the decision-makers, or those who are in a position to advise or guide them, feel they need assistance in understanding them better. It is at this point that analysis can provide help.

Problems can take on numerous forms. The focus of this thesis is on problems that involve opposed sociotechnical systems and require systems analysis approaches to understand and evaluate. Harold A. Linstone has described complex problems as having the following three attributes:

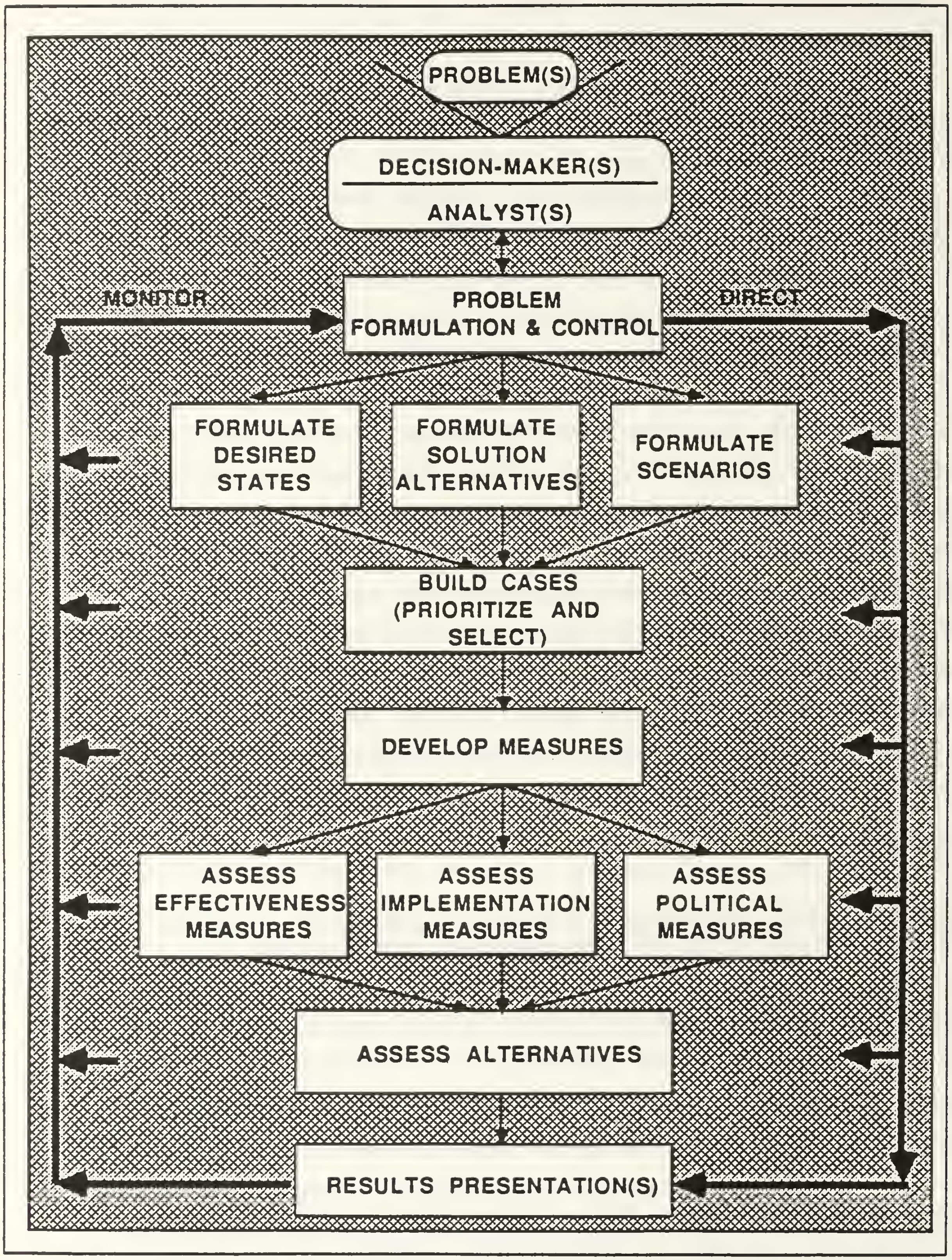

PROBLEM(S)
DECISION-MAKER(S)
ANALYST(S)
MONITOR
PROBLEM FORMULATION & CONTROL
DIRECT
FORMULATE DESIRED STATES
FORMULATE SOLUTION ALTERNATIVES
FORMULATE SCENARIOS
BUILD CASES (PRIORITIZE AND SELECT)
DEVELOP MEASURES
ASSESS EFFECTIVENESS MEASURES
ASSESS IMPLEMENTATION MEASURES
ASSESS POLITICAL MEASURES
ASSESS ALTERNATIVES
RESULTS PRESENTATION(S)

Figure 3.1 The Modular Analysis Process

1. ill-structured nature of the problem (typically sociotechnical systems);
2. significant policy and/or decision analysis content;
3. significant human aspects (societal or individual).

[Ref. 2: p. 5]

C. PROBLEM FORMULATION AND CONTROL

> A real pitfall is the failure to allocate and to spend a sufficient share of the total time available deciding what the problem really is. problems faced by the systems analyst frequently belong to that class in which the difficulty lies more in deciding what ought to be done than in deciding how to do it. ... Rather than be guided primarily by what the sponsor believes or states is the best approach, a good systems analyst will insist on formulating his own. It is a pitfall to give in to the tendency to "get started" without a lot of thought about the problem. [Ref. 16: p. 301]

The problem formulation and control module comprises the activities that are normally undertaken at the onset of an analysis. These activities constitute the first level within the MAP and serve to initialize the analysis process. It will be shown that in many respects, this module's activities make up a complete, although small-scale, study of the problem [Ref. 15: p. 127]. Figure 3.2 illustrates the six major components of this module, namely:

1. problem formulation and control management;
2. determining the analysis objectives;
3. characterizing the problem;
4. formulating an analysis approach;
5. completing an initial assessment, and;
6. developing solution management plans.

1. Problem Formulation and Control Management

The first aspect of the problem formulation and control module that will be considered here concerns module management. As mentioned earlier, the scope of this module's activities are sufficient to be considered a complete macro-analysis of the problem. Hence, to perform an efficient, effective analysis, some management of these activities is required.

The scope of activities accomplished in this management function are as listed below.

1. Get oriented by previewing and initially scoping the activities within the entire Problem Formulation and Control module as they apply to assessing the problem of interest.

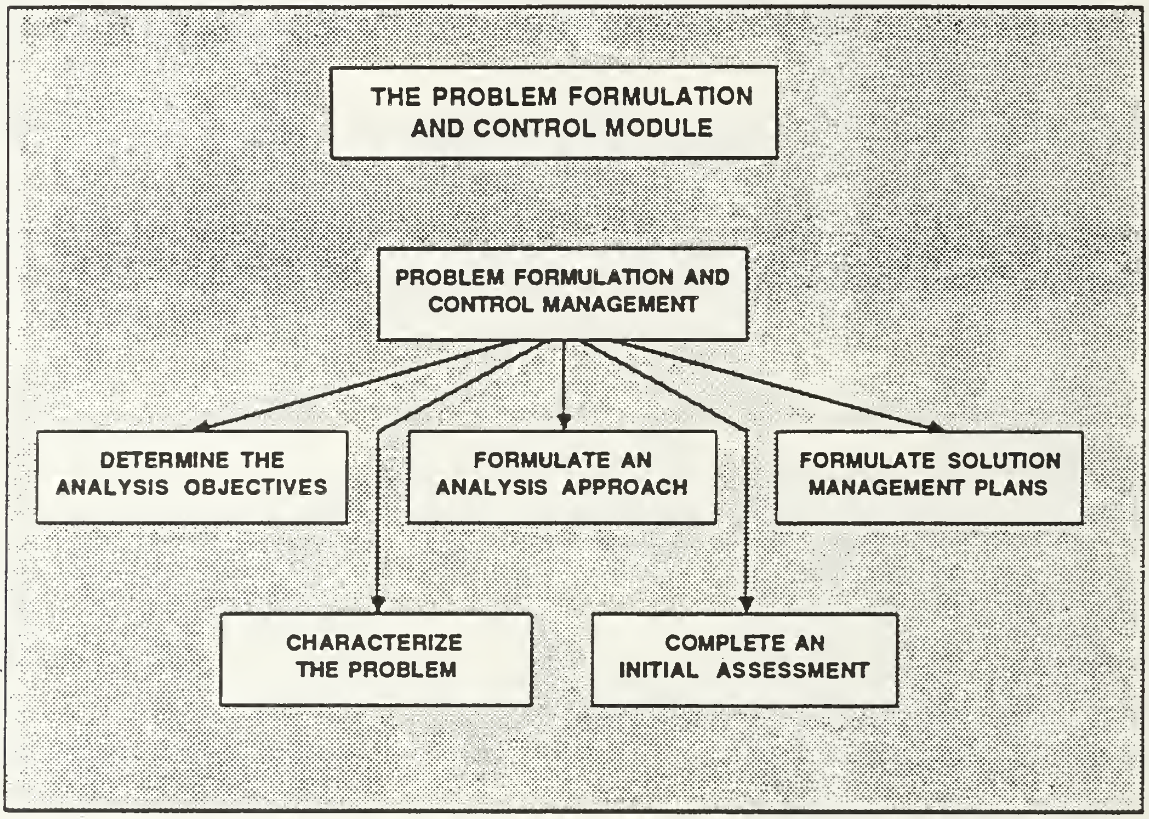

THE PROBLEM FORMULATION AND CONTROL MODULE
PROBLEM FORMULATION AND CONTROL MANAGEMENT
DETERMINE THE ANALYSIS OBJECTIVES
FORMULATE AN ANALYSIS APPROACH
FORMULATE SOLUTION MANAGEMENT PLANS
CHARACTERIZE THE PROBLEM
COMPLETE AN INITIAL ASSESSMENT

Figure 3.2 The Problem Formulation and Control Module

2. Given whatever information is available at the onset, develop some plans concerning what and who is required (or desired) to help perform this module's activities.
3. Recruit and structure an initial analysis team, if required.
4. Develop a schedule and resource allocation plan pertaining to this module.
5. Supervise and perform this module's activities.
6. Present the results of this module according to the directions of the tasker(s) or decision-maker(s), (they may be the same). This is typically in the form of a briefing or an issue paper [Ref. 15: p. 169].

The activities within the problem formulation and control module normally will require iterations back and forth between activities. This module may even need to be completely performed more than once in response to a decision-maker's feedback. For example, after seeing the initial results, the decision-maker may want to revisit this module at an increased level of detail or with a revised scope.

The following subsections will provide more detail on the nature of the activities within the problem formulation and control module.

2. Determining the Analysis Objectives

Analysis objectives provide some description of the destination of the analysis effort. Before one decides how to go somewhere, one must have at least some idea of what one's destination is. Determining the analysis objectives requires the answering of three primary questions. These questions are illustrated in Figure 3.3 and are listed below. They will be described in the subsequent paragraphs.

1. Who are the supported decision-makers?
2. What are the decision-maker(s)' analysis objectives?
3. How should the analysis support the decision-makers?

a. Identifying the Decision-Maker(s)

> Use of it (a systems analysis workbook) in about 20 studies suggest that the most difficult question the systems analyst has to answer, and the one whose answer has the biggest effect on project outcome, is Who are the problem posers and decisionmakers [Ref. 15: p. 164]?

Analyses are seldom performed for a single decision-maker who has full authority over acceptance of alternatives as well as over their implementation. Frequently, an analysis is performed for a principal decision-maker and his staff or for a decision-making organization, for example, the United States Congress, with divergent goals and biases. There are often several layers of decision-makers that must view a particular problem, with the result that the principal decision-makers who interface with the analysis leaders may not turn out to be the decision-makers making the final decisions from the results of an analysis. Edward S. Quade, in his book, *Analysis for Public Decisions*, illustrates the problem of viewing problems as if they had a unitary decision-maker in the following quote:

> as one Air Force officer put it to me -- don't consider your task to be one of telling the Chief of Staff what bomber to select, view it as helping the general's staff to solve an organizational problem in which selecting the next bomber is the driving entity. [Ref. 17: p. 315]

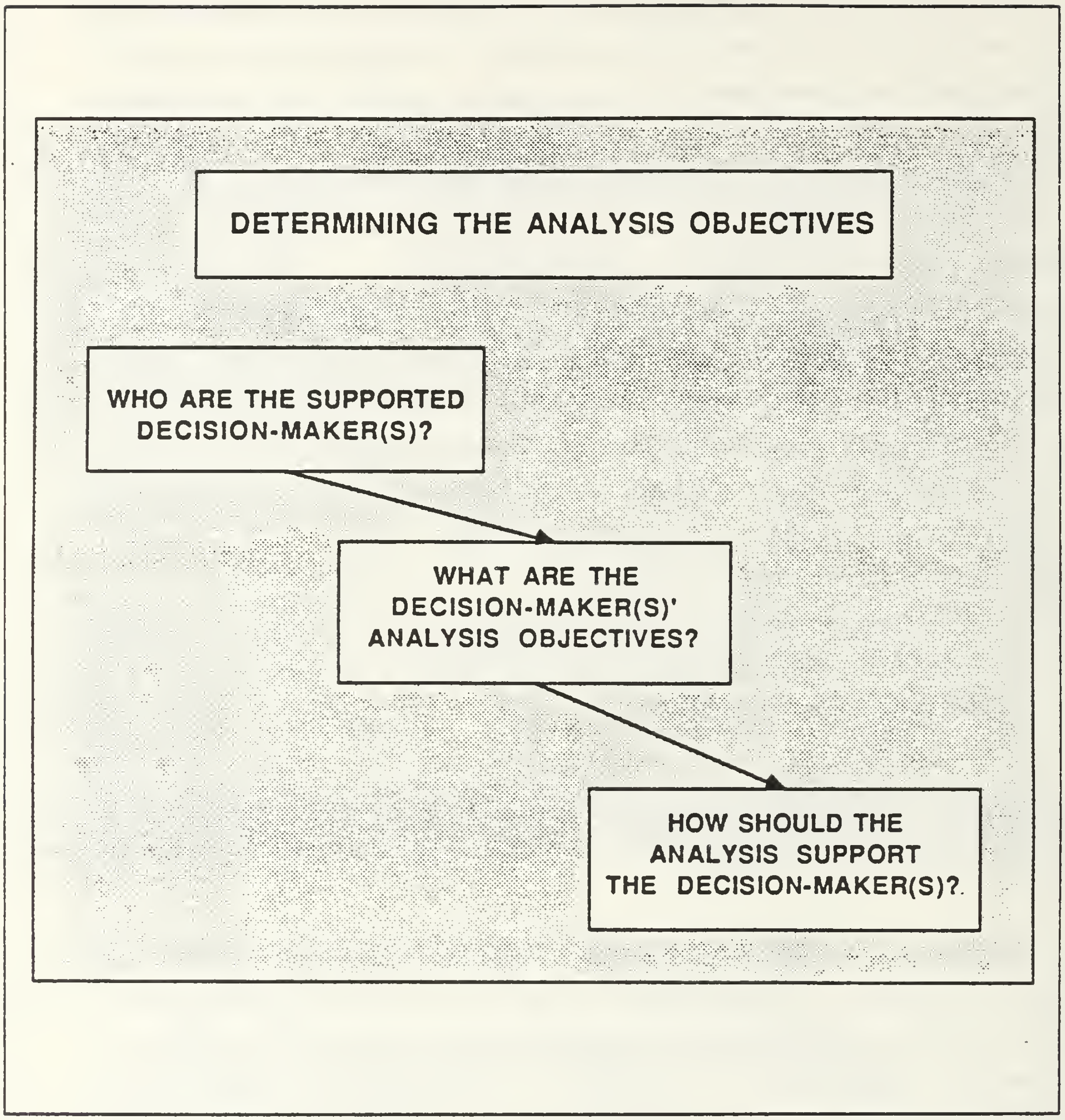

DETERMINING THE ANALYSIS OBJECTIVES
WHO ARE THE SUPPORTED DECISION-MAKER(S)?
WHAT ARE THE DECISION-MAKER(S)' ANALYSIS OBJECTIVES?
HOW SHOULD THE ANALYSIS SUPPORT THE DECISION-MAKER(S)?

Figure 3.3 Determining the Analysis Objectives

Given the above, an essential step in the analysis process is that of identifying who the decision-maker or decision-makers really are. This is not just a process of identifying who the tasker of the study is, but rather involves a careful assessment of those who will make and implement the decisions.

b. Identifying the Decision-Maker's Analysis Objectives

The second question, "what are the decision-makers analysis objectives?", is typically formed during the interactions between the decision-makers and/or taskers and the analysis leader(s). Analysis objectives may be quite detailed or, as is more often the case, stated in terms that need further refinement. At a minimum, the analysis objectives must include a statement of the problem to be analyzed as well as some idea of decision-maker expectations, support, and known constraints.

TABLE 3

IDENTIFYING THE DECISION-MAKER'S ANALYSIS OBJECTIVES

WHAT IS THE PROBLEM?

- Is the problem a subset of a larger problem?
- What is the history of the problem?
- What is the importance of the problem?
- What are the decision-maker(s) assumptions about the problem?

WHOSE PROBLEM IS IT?

- Who will use the results?
- Who will implement the results?
- Who else is interested in this analysis?

WHAT DOES THE DECISION-MAKER EXPECT FROM THE ANALYSIS?

- What question(s) does the decision-maker want help with?
- What, if any, are the expected/desired results?
- When does the decision-maker need the analysis results?

HOW DOES THE DECISION-MAKER EXPECT THE ANALYSIS TO BE PERFORMED?

- How much, and which (e.g., a particular analyst may be expected) resources are to be used in the analysis?
- What is the tasker's perceived role in the analysis effort?
- Preview the remaining modules of the MAP
    - Identify desired states, alternatives, and scenarios
    - Identify what assumptions the analysis will rest on
    - Identify what quantitative models are expected to be used
    - Etcetera

Table 3 provides some categories of questions that can be used by the lead analyst when trying to formulate the decision-maker's analysis objectives. These questions can be posed directly to the supported decision-maker(s), but could also be posed to whoever knows the decision-maker and the problem in issue well. While the primary intent of these questions is to gain an understanding of what the decision-maker(s) view of the problem is and what his goals are, the answers to these questions can also serve as the foundation for the analysis required in the next submodule, namely *Characterizing the Problem.* This is not intended to be an exhaustive list, but should help the analyst in not overlooking some key concerns.

c. Determine How the Analysis Should Support the Decision-Makers

Answering the third question, "how should the analysis support the decision-maker(s)?", is the final step in determining the analysis objectives. This step occurs either after the decision-makers' inputs have been received or when an analysis is not requested by a decision-maker, yet an analyst sees a need and decides to self-initiate an analysis.

This step often involves combining and prioritizing the inputs from one or more decision-makers. This may be a difficult process as different decision-makers frequently have different objectives. When divergent goals arise, it is important to note who are the principal decision-makers to be supported, and to develop the objectives accordingly. Once these integrated and prioritized analysis objectives have been developed by the analyt(s), then, if possible, these should be agreed upon by the key tasker and/or decision-makers.

3. Characterizing the Problem

Whereas the last submodule was involved with the determination of the analysis objectives, this current submodule, Characterizing the Problem, explores what the challenges are in meeting these objectives. These challenges, like those described in the "Scope" section of Chapter I of this thesis, are divided into three principal dimensions. Figure 3.4 revisits these dimensions and expands upon them by introducing the complex sociotechnical systems primarily associated with them.

The three dimensions illustrated in Figure 3.4 are distinguished by what sociotechnical systems they primarily focus on. For example, the External Challenge focuses in on the threat and hence is concerned with the enemy sociotechnical systems and their possible impact on the friendly sociotechnical systems of interest. These dimensions are further distinguished by the nature of the question that they are attempting to illumine. For example, the External Challenge is concerned with what is the nature of the threat. The Support Challenge is concerned with what are the nature of the limits that exist in addressing the threat. The final challenge, termed the

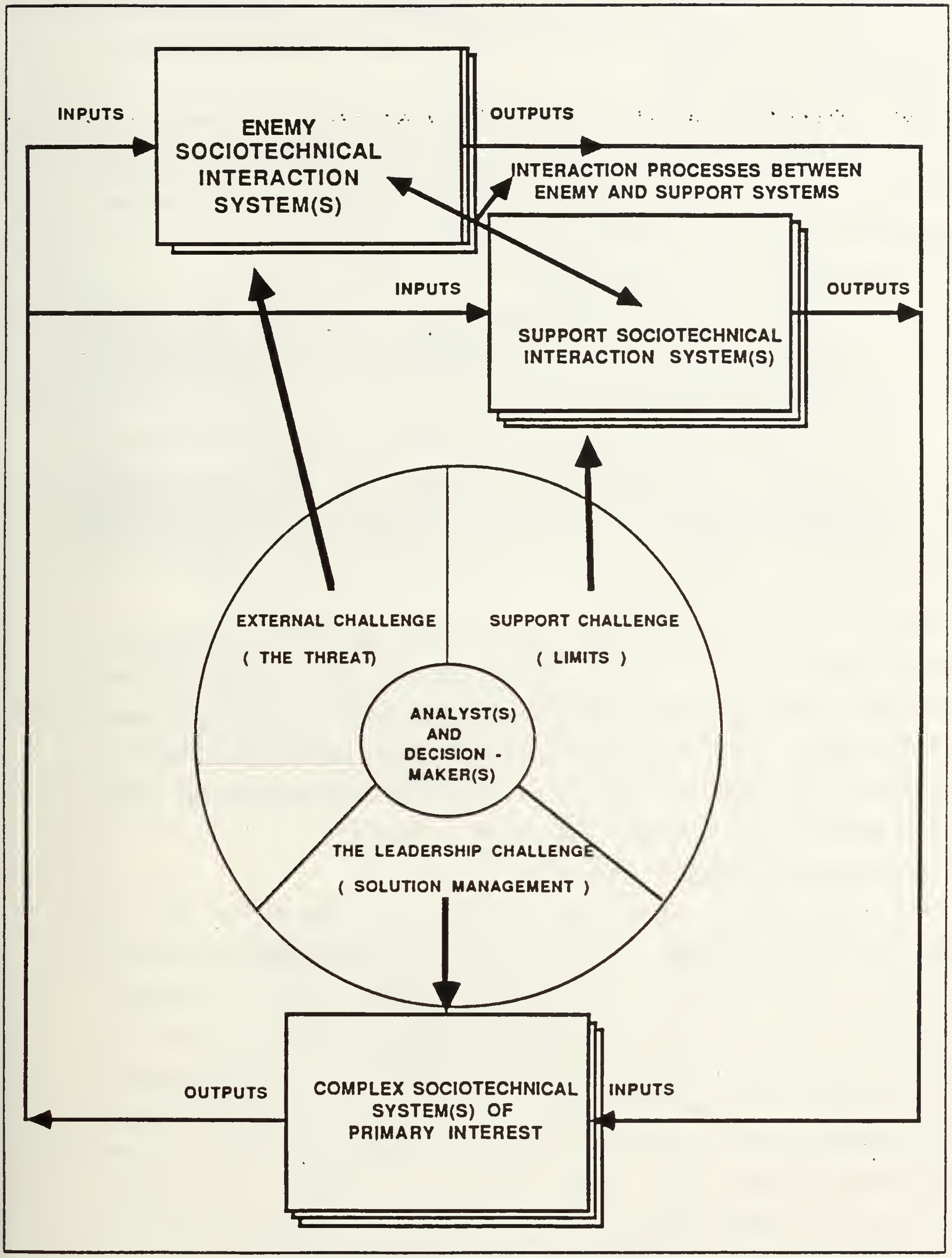

INPUTS
ENEMY SOCIOTECHNICAL INTERACTION SYSTEM(S)
OUTPUTS
INTERACTION PROCESSES BETWEEN ENEMY AND SUPPORT SYSTEMS
INPUTS
OUTPUTS
SUPPORT SOCIOTECHNICAL INTERACTION SYSTEM(S)
EXTERNAL CHALLENGE
(THE THREAT)
SUPPORT CHALLENGE
(LIMITS)
ANALYST(S) AND DECISION - MAKER(S)
THE LEADERSHIP CHALLENGE
(SOLUTION MANAGEMENT)
OUTPUTS
COMPLEX SOCIOTECHNICAL SYSTEM(S) OF PRIMARY INTEREST
INPUTS

Figure 3.4 An Expansion of a Problem's Three Challenges

Leadership Challenge, is concerned with solution management; that is, given the threat and support environments, what can be done to address these two challenges toward the accomplishment of selected goals.

Figure 3.5 illustrates some of the major actions that may be required to characterize the challenges associated with a selected problem. Each dimension has a parallel action that is accomplished in order to characterize a challenge. These actions will be explained in the following paragraphs.

a. Characterizing the External Challenges

Characterizing the external challenges involves identifying what is the nature and the context of the threat. Figure 3.5 illustrates the major activities that may need to be performed to accomplish this task.

The first of these activities is that of identifying and bounding the primary friendly systems of interest and the threat systems that interact with these systems according to the problem of interest. This is macro or large-scale form of bounding that is accomplished to identify the major sociotechnical systems that will be considered as part of the external threat.

The next step in characterizing the external challenges is that of identifying and bounding the major aspects of system structure and processes that pertain to the threat. This action involves generally defining the nature of the structure and processes relevant to the problem of interest that exist both within and particularly between the systems identified by the previous task. Chapter II of this thesis explains the terms "structure" and "process" as they are used throughout this thesis.

b. Characterizing the Support Challenges

The next activity required to characterize a problem is that of characterizing the support challenges. This activity involves identifying what is the nature and context of the challenges associated with gaining support to counter a threat. This activity has the same basic structure as that of the one used to characterize the external threat. The major differences occur in that the systems to be identified and bound will probably change significantly, in that the support sociotechnical systems typically involve other friendly or neutral or mutually opposed sociotechnical systems, rather than enemy sociotechnical systems. The possible exception to this occurs when factions within the enemy sociotechnical systems of interest may provide support or when the enemy sociotechnical systems can be reflexively controlled or influenced to unwittingly provide support.

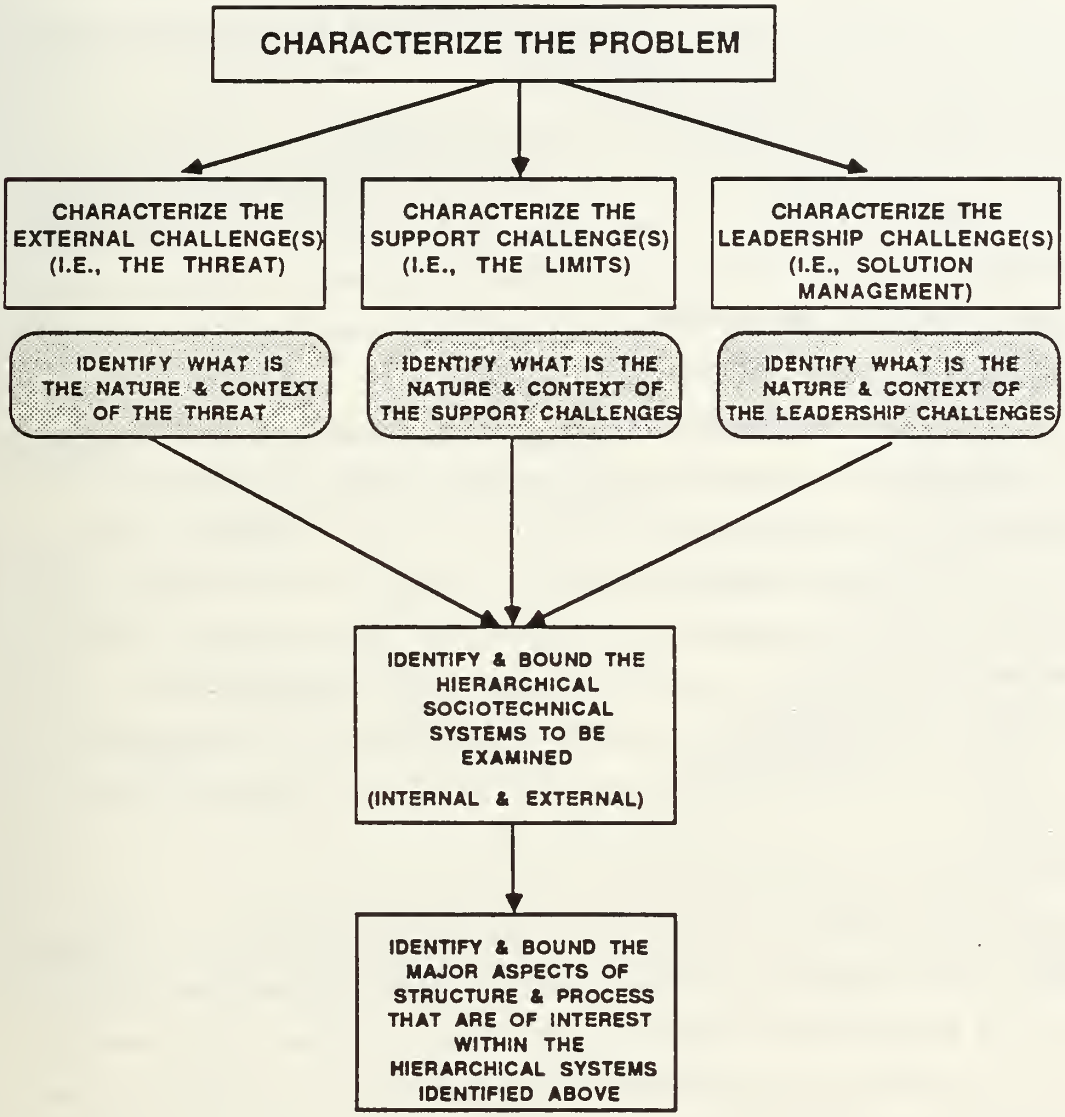

CHARACTERIZE THE PROBLEM
CHARACTERIZE THE EXTERNAL CHALLENGE(S) (I.E., THE THREAT)
CHARACTERIZE THE SUPPORT CHALLENGE(S) (I.E., THE LIMITS)
CHARACTERIZE THE LEADERSHIP CHALLENGE(S) (I.E., SOLUTION MANAGEMENT)
IDENTIFY WHAT IS THE NATURE & CONTEXT OF THE THREAT
IDENTIFY WHAT IS THE NATURE & CONTEXT OF THE SUPPORT CHALLENGES
IDENTIFY WHAT IS THE NATURE & CONTEXT OF THE LEADERSHIP CHALLENGES
IDENTIFY & BOUND THE HIERARCHICAL SOCIOTECHNICAL SYSTEMS TO BE EXAMINED
(INTERNAL & EXTERNAL)
IDENTIFY & BOUND THE MAJOR ASPECTS OF STRUCTURE & PROCESS THAT ARE OF INTEREST WITHIN THE HIERARCHICAL SYSTEMS IDENTIFIED ABOVE

Figure 3.5 Characterizing the Challenges in a Problem

c. Characterizing the Leadership Challenge

The last activity in charactering the problem is that of characterizing the leadership challenges involved with analyzing how to best address the external threat challenges, given the challenges associated with gaining support. This activity has the same basic structure as the prior two activities; however, once again, the sociotechnical systems to be bounded will most likely be changed. For this module, the sociotechnical interaction systems identified will be those that are involved with performing the analysis or with reviewing or using the analysis results.

4. Using Varying Analysis Perspectives to Bound the Problem

The previous subsection's activities that served to characterize the challenges inherent to the problem of interest all used some form of system bounding. The following paragraphs expand upon the concept of system bounding. In particular, the concept and utility of Analysis Perspectives, as adapted from Harold A. Linstone, will be discussed [Ref. 2: pp. 46-54].

Figure 3.6 provides a generic illustration of how the systems bounding categories are developed and used in the prior submodule's activities. Elements refer to entities, structures, and processes that are the building blocks for a subsystem within a sociotechnical system of interest. Subsystems refer to groups of elements which are functionally joined together for some purpose within the system processes. Other external systems are systems that do not directly interact with the primary system of interest. The ecosystem refers to the natural physical setting that all of the bounded systems are in. All of the other terms in this illustration were defined in previous sections of this thesis.

a. An Overview of Analysis Perspectives

Analysis Perspectives are an important consideration during the problem formulation stage of the analysis in that they help the analyst answer the question "how should I view a given system of interest?", rather than just "what is the system of interest?" Once the question of "how" a system should be viewed is answered, the structure and processes within the systems of primary interest become better defined. The following paragraphs will provide some definition to the term Analysis Perspectives.

The following paragraphs briefly explain a paradigm of Analysis Perspectives as developed in Harold Linstone's book, *Multiple Perspectives for Decision Making* [Ref. 2: p. 39]. It is beyond the scope of this thesis to fully examine the topic

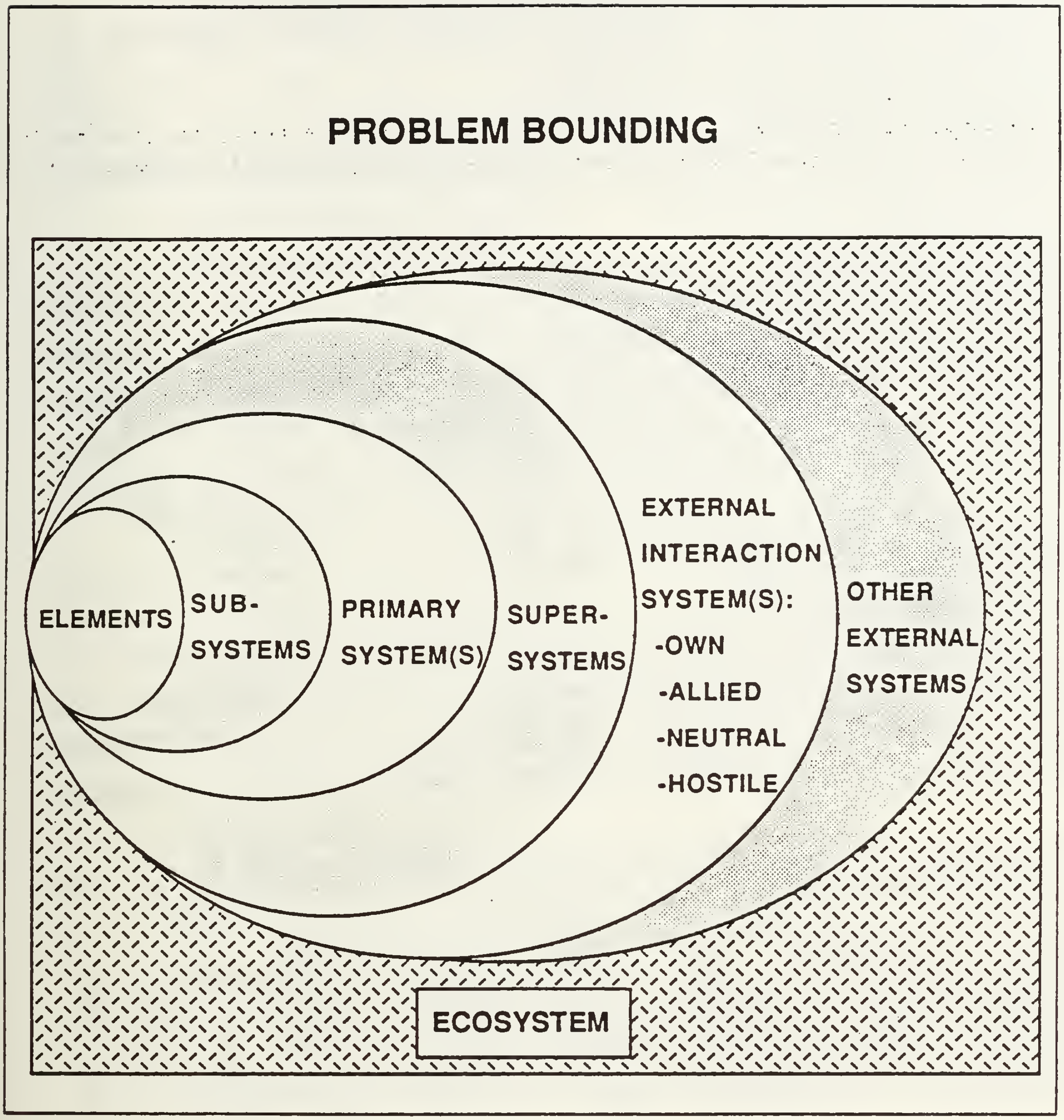


Figure 3.6 Identifying and Bounding Systems

of Analysis Perspectives. The remainder of this section will only provide an overview of its main constructs.

b. Why Use Perspectives?

The importance of considering Analysis Perspectives comes from the complex nature of the problems and systems of interest. If the scope of the problem only involved a machine's performance with little or no consideration required of the human aspects of the situation, then considering Analysis Perspectives may be of little help in reaching adequate solutions. However, the problems of concern for this thesis involve systems with significant human interactions.

c. How Systems Are Viewed

Linstone proposes the following three perspectives as important to consider at the onset of an analysis. These three are:

1. a technical perspective (T);
2. an organizational perspective (O);
3. and a personal perspective (P). [Ref. 2: p. 44]

The use of multiple perspectives in the problem formulation stage of an analysis helps the analysis team to keep from narrowing in on one perspective. Obviously, problems that deal with technological systems will necessarily be viewed from the T perspective, however, the O and the P perspectives may also lend special insight into a solution to the problem.

d. The Technical Perspective

A major reason for including Analysis Perspectives as one of the steps within the analysis process is because of the strong bias most analysts have for viewing problems from a strictly technical perspective rather than from the O or P perspectives. The following quote from Linstone illustrates this bias and one of its consequences.

> The United States as a culture is the most strongly T-oriented culture in the world. We love statistics and polls. A true baseball fan is awash in statistics, and a girl is a "10." We define quality of life (QOL) in terms of numerical indicators -- so that it would be more precise to label it quantity of life. The bias toward the T perspective is seen in the Central Intelligence Agency: "Technological cleverness is the pride of the U.S. intelligence ... But American supremacy in technical intelligence is profoundly misleading. It is not representative of the U.S. intelligence capabilities as a whole but stands in stark contrast. For in every other intelligence field -- human spies, analysis of data collected, and ability to conduct secret operations -- the U.S. intelligence community appears to be dangerously deficient (Toth, 1980:1)." [Ref. 2: pp. 46, 47]

According to Linstone, the technological perspective has dominated the systems, risk, and impact analysis literature. In this paradigm, systems are viewed in quantitative terms, with concepts like optimization, data analysis, and modeling, and with tools like cost-benefit analysis, system dynamics, econometrics, etcetera. The goals of the technological perspective, according to Linstone, are typically that of maximization of an expected utility or the determination of opportunity costs. [Ref. 2: pp. 46, 398]

While the technological perspective has proven its worth through the years and has received emphasis with such disciplines as Operations Analysis, other perspectives may play a vital role in the analysis. The next two subsections will examine these last two analysis perspectives. These subsections will outline the organizational and personal perspectives.

e. The Organizational Perspective

The organizational perspective, according to Linstone, views the world as affected and affecting organizations. Within this paradigm, organizations are sometimes viewed as living entities, with their own hopes, emotions, and needs. Changes to a system's structure or processes, (e.g., a policy change), are viewed as to how they will affect one organization versus other organizations. Hence, the concepts of security and influencing power are very important. [Ref. 2: p. 47]

Analysis within the O perspective is less likely to rely on model-based quantitative analysis. In fact, analytic tools are often mistrusted as being too academic, too unrealistic, too unpredictable, or too uncontrollable. While uniqueness within the T perspective is the rule, diversity may be expected as each organization views a problem from a different perspective. Final recommendations may be more influenced by organizational capabilities and the nature of the ties between other organizations. [Ref. 2: pp. 47, 401]

The importance of considering the O perspective is stressed in the following quote from Linstone.

> Perhaps the strongest argument for inclusion of this perspective is the realization that, in the political arena, highly technical information is usually, and properly, discounted in favor of social interests and considerations of values involved -- and these can never be adequately encompassed by a T perspective. Pressures emanate from institutions, regulatory agencies, special interest groups, and mass social movements. Illumination of the interplay of these pressures necessitates the O perspective. [Ref. 2: p. 48]

f. The Personal Perspective

The personal perspective, according to Linstone, views the world through the eyes and brains of individuals. The P perspective should bring in any aspects that impact the problem of interest and that pertain uniquely to individuals. Influencing agents such as charisma, leadership, and self-interest which may have a significant impact on a problem may only be understood using a personal perspective. [Ref. 2: p. 53]

An important step in the analysis process when using the P perspective is that of identifying the key people who impact a problem of interest. According to Linstone, personal probing is often essential in identifying key individuals and the role they play. The following quote from Linstone illustrates some of the difficulties in identifying the key individuals:

> There are beneficiaries and victims, entrepreneurs and users, regulators and lobbyists. They are the "hidden movers." These are individuals who, from a second- or third-level position, pull the strings that determine how things progress. (Attention is usually so keenly focused on the behavior of the puppets, which is overt, that the effect of the puppeteer, who is hidden from view, is ignored.) . . . . For less publicly prominent positions, the powers behind the throne usually remain obscure. [Ref. 2: p. 54]

5. Formulating the Analysis Approach

After characterizing the problem, the next stage of the problem formulation and control module is that of formulating the analysis approach to be used. Whereas the last submodule served to bound the challenges within the problem, this submodule will develop a solution methodology. The steps within this submodule are as follows:

1. Determine the key assumptions on which the analysis will rest;
2. Determine which analysis perspectives will be used in the analysis;
3. Preview and scope the activities to be performed in the remaining MAP modules.

a. Assumptions About the Problem

The first area to be considered in the formulation of the analysis approach is that of assumptions. From the formulation of analysis objectives through the rest of the analysis process, many assumptions will need to be made. The problem that often arises in analyses is not that assumptions are made, but rather that assumptions are not always stated explicitly. An analysis is only as good as the assumptions upon which it is built. Throughout the analysis process, if these assumptions have been stated explicitly, then they can be reviewed, and if necessary, be adapted to reflect a growing understanding of the problem and its possible solutions.

Another reason for explicitly stating one's assumptions at the front-end of an analysis, is that it gives the people within the analysis process, including the decision-maker(s), a chance to question them. After the analysis is nearly complete or when the results are being presented to a decision-maker are not the times to find that a key assumption is not considered to be valid by important people within the decision chain.

This thesis emphasizes assumptions within the problem formulation area because it is at this time that key interactions typically occur with decision-makers. Although this is the only time that assumptions will be discussed at length within the thesis, assumptions will normally be made throughout the analysis. These assumptions, as far as is practical, should continue to be explicitly stated.

b. Selecting the Analysis Perspectives

After the key challenges have been initially assessed in the prior submodule, and important question arises: "How much of the overall analysis effort should be dedicated to the Technical versus Organizational versus Personal perspective?" -- as described earlier in this thesis. A good portion of this question should have already been answered because of the activities of the prior submodules, such as the bounding aspects of the previous *Characterizing the Problem* submodule.

Linstone recommends that if little is known about the relative importance or impacts that the various perspective assessments might have on analysis, then the analysis resources should be equally allocated between the three perspectives until a refinement seems in order. He recommends this over the nearly ninety percent that is typically allocated towards the Technical perspective in the analysis of sociotechnical systems. [Ref. 2: p. 359]

c. Previewing and Scoping the Remaining MAP Modules

After the first two steps in this submodule have been performed, then it is appropriate to preview and scope the remaining modules within the MAP. This step does not involve actually performing the modules, even in a macro sense, but rather sets the initial course for both the initial and in-depth assessments to follow. Completing this activity also sets the stage for the last two activities within the Problem Formulation and Control Module, namely, developing the solution management plans and completing an initial assessment.

6. Developing the Solution Management Plans

The solution management plans, as illustrated in Figure 3.7, are formed during the interactions between analysis leaders, the decision-makers, and the analysis team(s). These plans serve to formally communicate the analysis objectives to the analysis team and are the principal vehicle for guiding and controlling the analysis effort.

Figure 3.7 shows the many areas that would normally need to be considered in the planning process. It is beyond the scope of this thesis to go into an explanation of all of these plans; however, the supervisory, activities, information, additional support, and integrated plans will be briefly discussed.

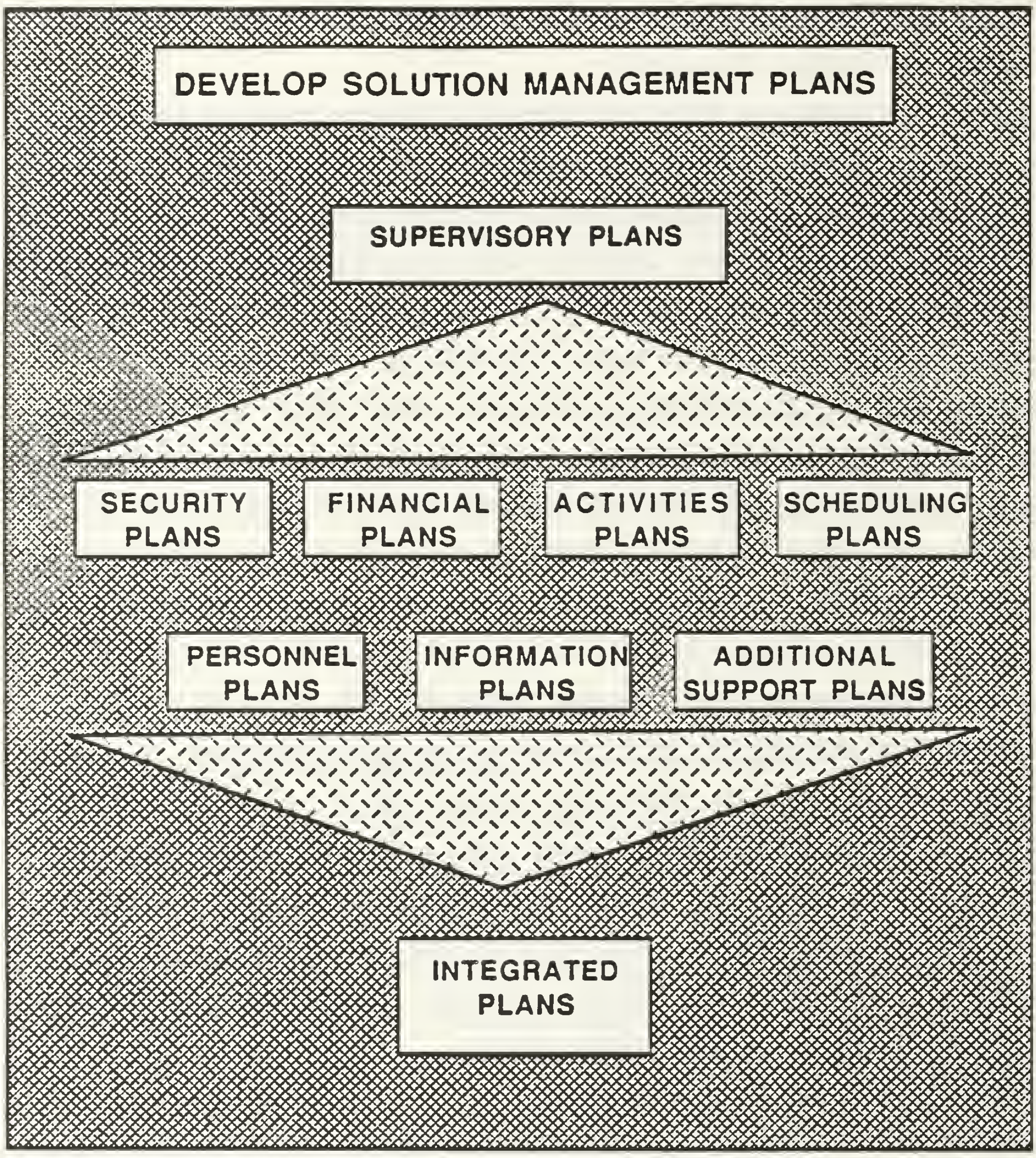


Figure 3.7 Solution Management Plans

Supervisory plans outline how the project will be managed. Included within this plan is a list of who the personnel or organizations are who are tasked to the project. In addition, these plans may indicate how these tasked people or organizations are functionally attached to the project. For example, these plans may indicate whether they will be working on the project full time, or part time while performing other tasks. Memorandums of understanding between organizations or people may be desired to formalize these task relationships.

The supervisory plans should also outline what the responsibilities of each team or team member are. These responsibilities include not only analysis responsibilities, but also those involving management. These plans, as with all the plans to be discussed here, should be dynamic and adaptive. That is, they need to be periodically reviewed and updated to reflect the dynamics of the "real world" analysis environment.

Activity plans should establish the general flow of activities within an analysis. The MAP developed in this thesis is intended to be used as a generic guide to structure these activities for use in a specific application. These activity plans should outline the analysis methodology (as developed in the prior submodule) and provide an initial schedule for the major activities within each phase of the analysis. It is suggested that these analysis plans include a macro-level analysis during the Problem Formulation and Control module in order to validate the methodology early on and to get an indication of what the results might yield. The next submodule in this thesis will discuss this initial assessment in more detail.

The information plan is used to establish a library function within a complex project. In addition, these plans may establish what the information needs for the project are, how these needs will be met, and what the individual or organizational information responsibilites are. It is important to note that in these plans, it is wise to outline what the analyst's responsibilities are in the way of documentating their analysis. The following quote of Hugh J. Miser emphasizes the importance of proper documentation. [Ref. 15: p. 301]

> First, the issue of documentation should be kept in mind from the beginning. The work should be documented as it proceeds, so that, at its end, when attention is properly focused on communicating the findings and following up on them, it will not be necessary to return to the earlier work to reconstruct--perhaps with considerable difficulty--what was done. [Ref. 15: p. 301]

The additional support plans involve any plans required that were not listed in the prior blocks in Figure 3.7. Numerous forms of plans may be deemed necessary to efficiently and effectively perform an analysis, such as those involving resource allocations (e.g., computer resource planning), logistics planning, contracts planning, to name a few.

Integrated plans are, as the name implies, those that review the other plans and insure that the plans dovetail with one another. These plans may merge with other plans such as those involving activities and scheduling and finances.

7. Completing an Initial Assessment

A critical step in the Problem Formulation and Control module is that of conducting an initial assessment. This assessment is important in that it acts as a valuable form of early feedback to the decision-maker and/or client so that major analysis adjustments can be make, if required, before proceeding on with the bulk of the analysis effort.

A common vehicle for representing the results of an initial assessment is the issue paper or an issue briefing. Many formats exist for these issue papers and briefings. For example, the National Defense University's *Joint Staff Officer's Guide* provides several good *paper* formats suited for differing military situations. The general intent of these papers and/or briefings are to explain the nature of the problem and to succinctly show where the analysis is heading, how it is going to be performed, and what are the known or expected results, if any.

D. FORMULATING THE DESIRED STATES

Formulating the desired states has the purpose of identifying what goals, capabilities, or objectives are desired for a solution set to a given problem or problems. The desired states are different than the analysis objectives in that the analysis objectives relate to the analysts' activities. In contrast, the desired states relate to the system of interest. The desired states are the destinations, whereas the solutions are the means of reaching these destinations.

For the purposes of this thesis, these desired states fall into three broad categories: capability objectives, implementation objectives, and political objectives. Each of these categories will be described in the subsequent paragraphs and are graphically illustrated in Figure 3.8.

FORMULATING THE DESIRED STATES

CAPABILITY OBJECTIVES	IMPLEMENTATION OBJECTIVES	POLITICAL OBJECTIVES
LEVELS OF: - SURVIVABILITY OBJECTIVES - ENDURANCE OBJECTIVES - ACCURACY OBJECTIVES - SECURITY OBJECTIVES - ETCETERA	LEVELS OF: - COST OBJECTIVES - SCHEDULE OBJECTIVES - MANNING OBJECTIVES - TECHNICAL RISK OBJECTIVES - ETCETERA	LEVELS OF: - FISCAL SUPPORT OBJECTIVES - PROGRAMMATIC SUPPORT OBJECTIVES - LEGAL RISK OBJECTIVES - REDUCTION OF RESISTANCE OBJECTIVES - ETCETERA

Figure 3.8 Formulating the Desired States

1. Formulating Capability Objectives

Capability objectives, for the purposes of this thesis, refer to the performance capabilities (or states) that are desired, given certain threats and scenarios, for the primary systems of interest. These capability objectives are not normally system implementation specific, rather, they are applicable to current or proposed systems in a generic sense. In other words, these capability objectives are desired states, independent of how these objectives are obtained through specific implementations. They would normally be applicable to all the alternatives for changes to existing systems or for future systems. [Ref. 18: p. 7]

An example of some capability objectives would be the strategic capability levels specified by the Joint Chiefs of Staff. The lowest of these levels describes some minimum required capabilities if certain national objectives are to be met. Each subsequent level subsumes the prior level but adds additional capabilities that would be required to reach other national objectives. These graduated levels help to establish benchmarks around which alternative systems can be evaluated. If decision-makers want to obtain certain national goals, then they can see what capabilities would be required (the desired states) to obtain those goals. Analysis can then be performed to determine how well a current desired state in the form of capability levels is actually being obtained and where shortfalls are occurring.

The value of having several capability levels specified, as in this example, is that it allows the desion-makers more flexibility on what actions to take given varying budget and resource constraints. It also allows the decision-makers to have a sensitivity analysis about what the trade-offs between levels might be.

Capability objectives can be stated in terms of how well certain system processes are performed, such as missions and functions. Other ideas for generating capability objectives, if they are not provided at the beginning of an analysis can be found by reviewing the "Characterizing the Problem" activity where aspects of the system structure and system processes were bounded. In addition, other ideas for capability objectives can be generated by previewing the effectiveness measures to be discussed in later sections of this thesis and then iterating back to this module.

2. Formulating Implementation and Political Objectives

Implementation objectives are those that specify what the desired states are for such areas as cost, risks, and system transitioning [Ref. 19: p. 7]. These objectives may be dependent on levels of capability objectives, as discussed in the previous paragraphs. These areas are further described in the sections that follow in this thesis that describe implementation measures.

Political objectives are those that involve specifying what are the desired states in the way of support or reduced resistance from those who can impact the solution environment. These political objectives will likely be dependent on the capability and implementation objectives that have been established. In addition, these objectives may be more directly influenced by specific system alternatives, and hence, these objectives are not necessarily generic. Political objectives are discussed further in the sections of this thesis that discuss political measures.

E. FORMULATING SOLUTION ALTERNATIVES

The next major module in the MAP, as illustrated in Figure 3.1, is that of formulating alternative solutions. This module occurs at the second level of the MAP and would typically be developed in conjunction with the formulation of desired states and scenarios, the other two modules at this level.

Since the goal of the analysis process is to identify to the decisionmakers what are the pro's and con's of alternative courses of action, as well as perhaps developing schemes to rank these solution alternatives, this step in the analysis process needs careful attention. If this step is done with too much haste, excellent alternatives may never even be considered.

To facilitate the process of formulating alternatives, several techniques can be used. One technique is the breaking down of alternatives into general, and possibly divergent classes of solutions. For example, these solutions can involve trade-offs between offensive and defensive, active and passive, brute force versus deceit, psychological versus technological, many small systems versus a few large systems, centralized versus decentralized, light and fast versus slow and heavily armored, stationary versus transportable versus mobile, etcetera.

In addition to developing broadly dimensioned solution classes as discussed in the previous paragraph, other techniques can be used to generate alternative solutions. For example, soliciting expert opinion outside of the analysis team can generate some new solutions. In addition, the development of an analysis team with an interpardigmatic problem solving mix as well as an interdisciplinary mix, will help yield a richer solution set [Ref. 2: p. 358]. For example, if a goal is established to force an opposed nation to negotiate a settlement in a conflict, the solutions that are proposed may be quite different between a politician, a military man, and an economist. The politician may seek to bring pressure to bear on the opponent through threatening to weaken the national leadership's power base by aiding competing political factions within the country. The military man might recommend an increase in the number of offensive missions against the enemy. While an economist might suggest flooding the opposed nation with counterfeit money to help destroy the nation's economic base.

F. FORMULATING THE SCENARIO

Formulating scenarios is the last module in the second level of the MAP. The activities that typically are performed in this module are those of bounding the probable or possible activities that would occur between the enemy, friendly, and neutral sociotechnical systems of interest. In addition, the associated environmental activities that interact with these systems would be bounded, such as weather phenomena.

Developing realistic scenarios is an essential but, at times, very difficult process. These difficulties often arise because of the lack of historical data on which to build a projection for the timeframe in interest. For example, nuclear war scenarios developed for today's analyses are built on many assumptions because of the limited information from current experience of this form of warfare, given the new technologies and because of unknown capabilities and intentions of the enemy.

When little historical data is available to predict the most likely scenarios for analysis, the normal course available to analysts is to construct ones using intuition and creativity. This creation process is only as good as the analysts' understanding of the enemy, friendly, allied, neutral, and environmental systems.

During the scenario development process, the analyst should carefully consider the *world views* of the enemy in order to make logical predictions. If the *world views* of the enemy are not understood by the analysis teams, outside help should be should be sought. The consequences of not understanding the enemy within the sphere of a given problem are that the analysts will be likely to mirror-image or superimpose their own beliefs or practices on the enemy, even if these beliefs are far from those of the enemy.

When developing scenarios, it is important that not only the most likely scenarios are examined, but that other possible scenarios are examined. The key word here is "possible." If scenarios are only based on intelligence estimates about what is expected from the enemy, then some unfortunate surprises may occur. History is repleat with examples of where the enemy did the unexpected and gained the victory. Obviously, all possible scenarios cannot typically be examined. However, developing scenarios that represent a range of technically and operationally feasible cases can serve to bound the problem. For example, on one project that the author worked on, the team developed three major scenarios. These scenarios ranged from a baseline threat, to ones that were progressively more aggressive, either operationally or technologically. In addition, excursion scenarios were developed during the analysis to answer some of the "what if" questions that arose. With these three scenarios, it was a relatively straightforward process to check to see how various alternative solutions fared when faced with different threat levels.

A final word about scenarios is that the three perspectives that were described in the problem bounding subsection of this thesis can also serve to illuminate aspects of possible threat scenarios. Viewing the world through the these three perspectives can insure that a broad enough approach has been taken for the scenario development. One example here is that if only the technological perspective is used, then only rational decisions will be typically expected from the enemy. If a personal or organizational perspective is used, a different set of decision possibilities may arise, which would not seem strictly rational from a T perspective.

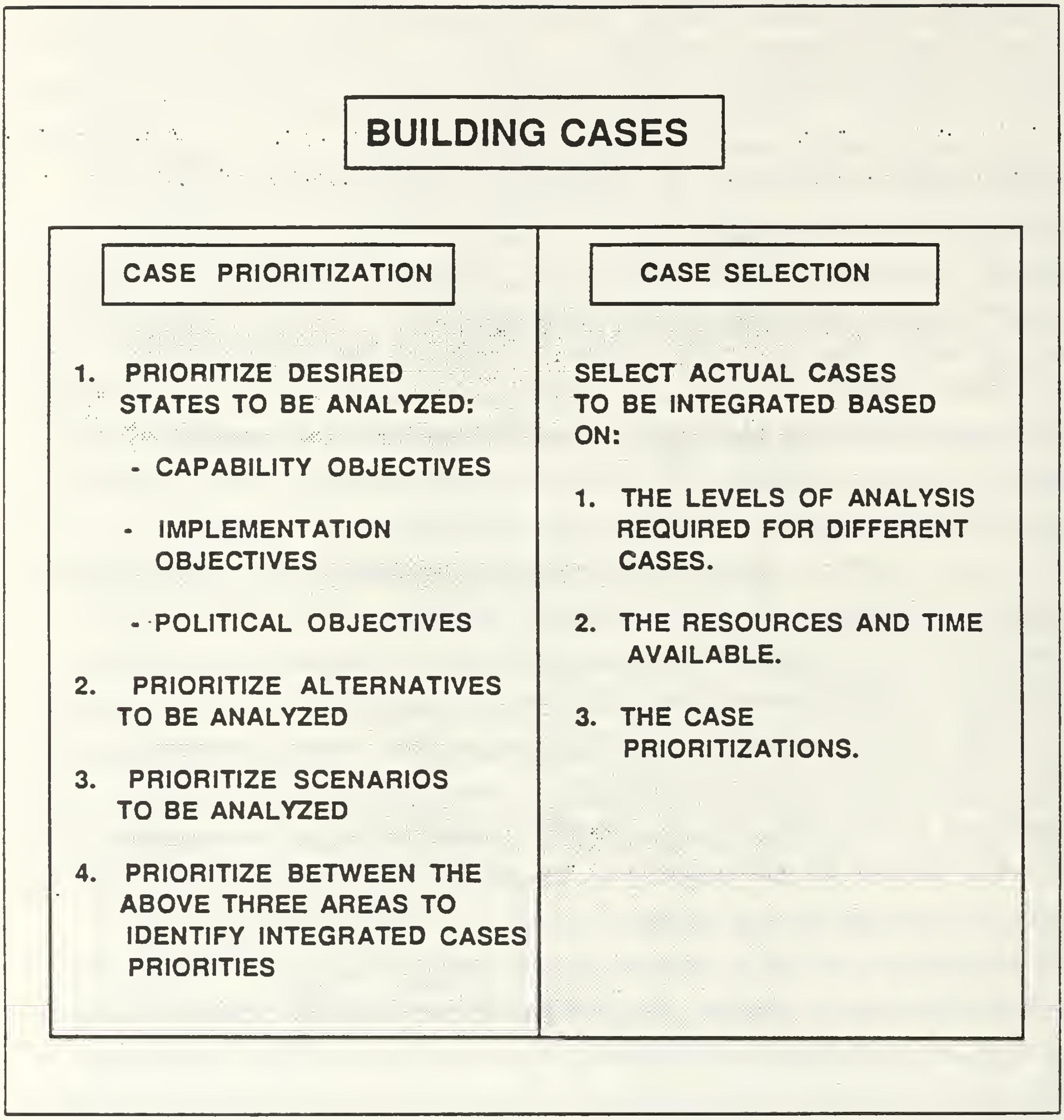
G. BUILDING CASES

The next module in the MAP, as illustrated in Figure 3.9, is that involved with the building of cases for analysis. This activity comprises the third level of activity within the MAP and occurs after the formulation of the initial desired states, solution alternatives, and scenarios. The module's purpose is to narrow the focus of the analysis effort by limiting the number of cases to be examined.

There are two primary activities that are performed in the Case Building module. The first of these activities is that of case prioritization and the second is that of case selection. Each of these activities will be discussed in more detail in the following paragraphs. The prioritization activity requires the analyst to review the findings of the second level of the MAP, namely the desired states, the alternatives, and the scenarios. The purpose of this review is to determine which of the desired states, alternatives, and scenarios must be examined in order to meet the analysis objectives.

The prioritization activity is required because frequently there are a very large number of possible cases to consider. For example, on one project the author worked on, there were two multi-faceted capability levels to examine, over fifteen alternatives to consider, and six scenarios (with variations). Given the limited resources that this project had and the large number of cases that this effort could possibly have considered, it became necessary to limit the number of cases considered in order to stay within the limits of the project's analytic resources.

Figure 3.9 breaks down the prioritization activity into its constituent parts, specifically, four steps. The first of these steps is shown to be that of taking the capability, implementation, and political objectives identified during the Formulate Desired States module and prioritizing them according to their importance for inclusion in the cases to be analyzed. An example of such a prioritization would occur if a key



BUILDING CASES

CASE PRIORITIZATION

1. PRIORITIZE DESIRED STATES TO BE ANALYZED:
   - CAPABILITY OBJECTIVES
   - IMPLEMENTATION OBJECTIVES
   - POLITICAL OBJECTIVES
2. PRIORITIZE ALTERNATIVES TO BE ANALYZED
3. PRIORITIZE SCENARIOS TO BE ANALYZED
4. PRIORITIZE BETWEEN THE ABOVE THREE AREAS TO IDENTIFY INTEGRATED CASES PRIORITIES

CASE SELECTION

SELECT ACTUAL CASES TO BE INTEGRATED BASED ON:

1. THE LEVELS OF ANALYSIS REQUIRED FOR DIFFERENT CASES.
2. THE RESOURCES AND TIME AVAILABLE.
3. THE CASE PRIORITIZATIONS.

Figure 3.9 The Case Building Module

decision-maker felt that one set of capability objectives were more important than another set for evaluating the alternatives against.

The second step, according to Figure 3.9, is to prioritize the alternatives to be considered. These alternatives typically involve some variations in, or. additions to, a system's architecture, whether its structure, processes, or both. As with the desired states described in the previous paragraph, certain alternatives may be of more interest to a key decision-maker, or certain alternatives may seem particularly promising, hence, these alternatives would take precedence in the case building ranking process.

The third step in the prioritization activity is that of ranking the scenarios according to their importance to the analysis objectives. For example, if a given scenario is accepted by the military community and is considered to be a likely course of events by the intelligence community, then this scenario might have a higher priority for analysis than other scenarios considered less likely. However, if a certain scenario is possible, but is considered less likely, it may take on a higher priority if it points out a catastrophic or significant weakness in one or more of the alternatives under consideration.

Whereas the first three activities under the heading of case prioritization are concerned with prioritizing cases within the prior modules (i.e., the three modules in the second level of the MAP), the next activity prioritizes cases between the three modules. For example, it may be more important to evaluate a particular system alternative against a scenario that is considered to be less important for most of the analysis, yet for this particular alternative a normally less important scenario points out one of the strengths or weaknesses with the particular alternative. Hence, the less important scenario would take priority over the scenario that most of the other systems would be evaluated over first. Another example is that even if there are say, four capability objective levels that are of interest to a decision-maker, it may be decided that it is more important to analyze every alternative over only one of these capability levels, with every scenario, versus analyzing only some of the alternatives over all four of the capability levels.

The second major activity of the Case Building module is that of case selection. Case selection occurs after the four steps in the case prioritization activity have been completed. The case selection activity consists first of determining what type of analysis is required for the various cases (in accordance with the analysis approach previously determined during the Problem Formulation and Control module). Once this has been done, then a selection of the specific cases to be considered can be made, given the constraints imposed by the limited resources available to conduct the various analyses. It is possible to consider a very large number of cases, as long as only a restricted number of cases are analyzed with resource intensive approaches. For example, many cases can be analyzed qualitatively based on expert judgment, while only a few cases may be considered requiring extensive computer software development time. Hence, case selections should be conducted in such a way as to identify which cases will be analyzed using which approach or approaches.

H. DEVELOPING MEASURES

1. Section Overview

The next activity within the MAP is that of developing measures to prepare for the assessment of the previously defined cases. These measures will typically be used to assess the strengths and weaknesses of each of the alternatives within the context of the cases developed in the previous module.

This section has two major remaining divisions. The first will explain the types of measures that may be required in an analysis. The second division will briefly explain some principles that can be applied to the selection of measures. The following paragraph will overview the topic of measures as will be described in the first division.

Measures, for the purpose of this thesis, will fall into three broad categories and make up what will be called the *global measures set.* These three categories are effectiveness measures, implementation measures, and political measures, and are illustrated in Figure 3.10. These categories parallel the three categories of desired states as described in the second level of the MAP. For example, effectiveness measures relate to the capability objectives discussed in the section on desired states. The other two types of measures use the same name as the parallel types of states, specifically, implementation and political. Each of these categories of measures will be discussed in the following paragraphs.

2. Effectiveness Measures

Effectiveness measures are those that can be used to assess the merits of one alternative versus another within the spheres of system structure and system processes. These measures are used to evaluate how well or how poorly alternatives address the external challenges or threats of interest. The effectiveness assessments are made in relationship to particular desired states (as described earlier in this chapter in the section on capability objectives) or in an absolute sense. For example, if alternative systems can track varying numbers of specified targets, the effectiveness measure could be stated in the absolute sense of how many targets each alternative could track, or in the relative sense of how many more (or less) targets could an alternative track compared to a reference number (i.e., a desired state expressed in terms of a specific number of targets that can be tracked).

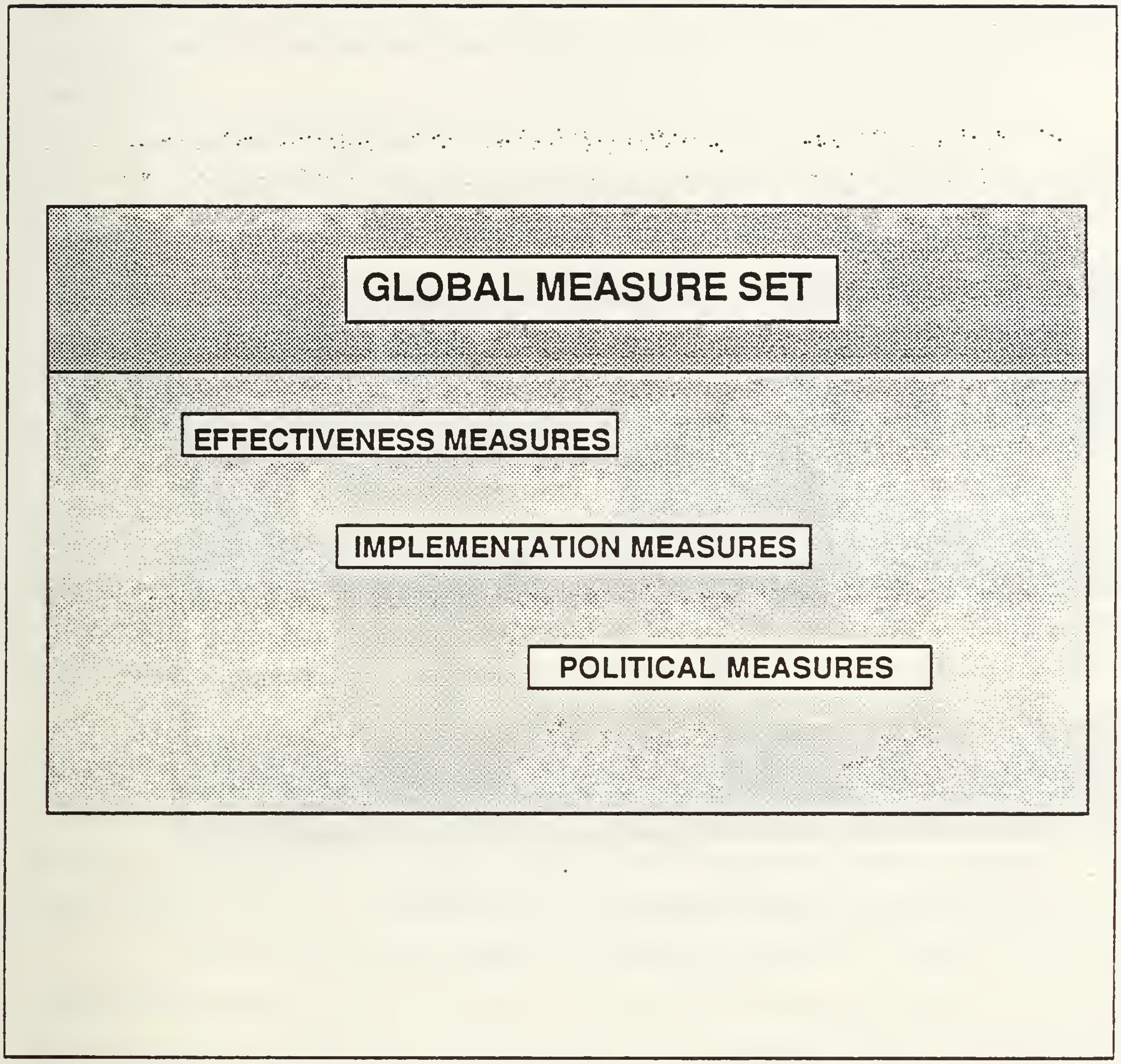


Figure 3.10 The Global Measures Set

Figure 3.11 shows the two major divisions of effectiveness measures: structural measures and process measures. This figure also shows the next level of decomposition with respect to these two divisions. As was discusses in Chapter II of this thesis, there are two principal aspects to a system's structure, namely entities and entity relationships. Just as there are two aspects to a system's structure, there are two types of measures to describe these differing aspects, as illustrated in Figure 3.11.

The process measures are also divided into two major subdivisions. The first involves measures that are classified based on the highest level internal or external

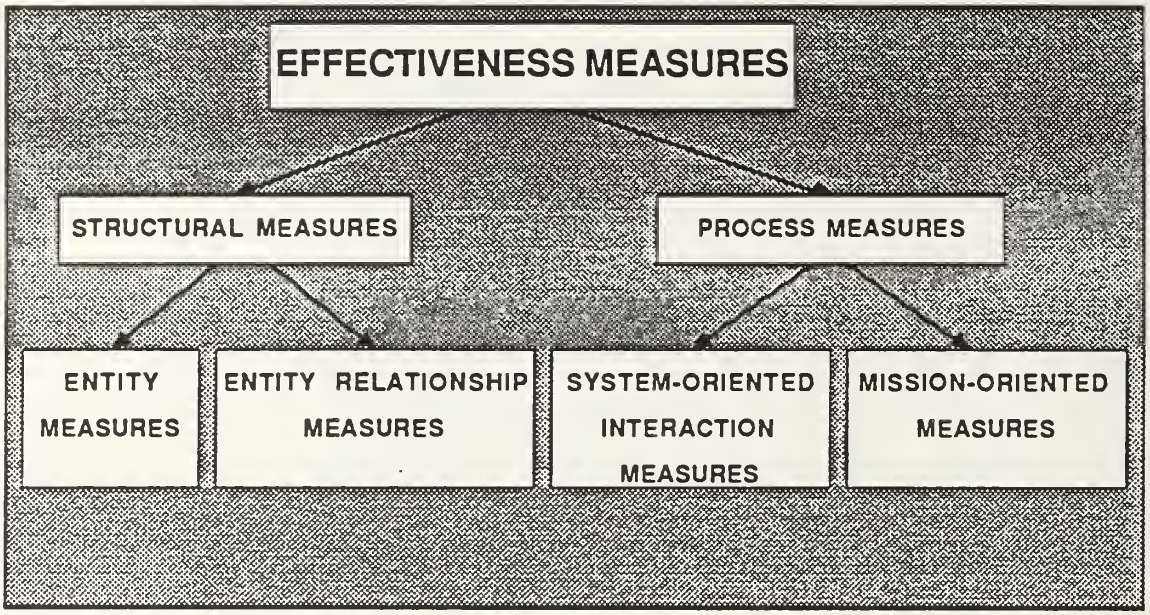

EFFECTIVENESS MEASURES
STRUCTURAL MEASURES
PROCESS MEASURES
ENTITY MEASURES
ENTITY RELATIONSHIP MEASURES
SYSTEM-ORIENTED INTERACTION MEASURES
MISSION-ORIENTED MEASURES

Figure 3.11 Effectiveness Measures

system or supersystem they interact with. These system-oriented interaction measures are further divided by whether they describe the interaction processes internal or external to the the systems or supersystem(s) of interest. These divisions will be explained in more detail in subsequent paragraphs.

The second subdivision of process measures are designed to assess mission accomplishment at various levels within the mission hierarchy (i.e., supermission measures, mission measures, function measures and task measures). Both divisions of the structural and process measures will be described in more detail in the following paragraphs.

a. Structural Measures

A structural measure is one which describes some aspect of a system's structure and that meets the following two criteria.

1. The measure has meaning at any instant in time. That is, the measure does not require a specific time interval in the context of a scenario to measure. These measures can involve time (for example, the maximum and minimum speed range of a system), but only in the sense of inherent system potentials that are independent of specific scenarios.
2. The measure has meaning outside of the context of a system's specific mission-oriented process within the sphere of a scenario.

The first division of structural measures involves entity measures. Entity measures describe some aspect of a system's entity or group of entities, in order to compare one alternative to another. These entity measures are static in that they do not measure mission-oriented processes in the context of a scenario. However, these entity measures can change in response to a system process.

Some examples of entity measures are shown in Table 4. This table shows that entity measures can assess physical characteristics, logical characteristics, and potentials inherent with the entity or entity group. This table is not intended to provide an exhaustive list of entity mesures, but rather shows some examples of the types of areas that may be important in the assessment of each alternative's worth.

The second major division of structural measures is made up of entity relationship measures. These measures, like the entity measures, are static in that they do not describe a system process in the context of a scenario. Table 5 provides some examples of how the entity relationship measures could be organized. Many other ways could be chosen to distinguish different types of entity relationships, depending on what may be important within a given problem.

b. Process Measures

A process measure is one which describes either the activities or the results of activities that are associated with a particular system of interest. These measures include those that are controlled by the primary system of interest as well as those that impact the missions of the system of primary interest but that are not directly under the system's control. Examples of the latter types of processes were provided in Chapter II of this thesis, and include measures associated with allied, hostile, neutral and environmental processes.

TABLE 4

EXAMPLES OF ENTITY MEASURES

THESE ARE MEASURES THAT DESCRIBE A SYSTEM'S ENTITIES, INDEPENDENT OF A SCENARIO AND MISSION-ORIENTED PROCESS

1. PHYSICAL CHARACTERISTICS
    - Weight, size, shape, color, composition
    - Age, sex, race
2. LOGICAL CHARACTERISTICS
    - Identity lables
        - -- Name, citizenship, make, model
    - Authority/Responsibility indicators
        - -- Ranks and titles
3. POTENTIALS
    - Logical
        - -- Training, specialty, and skill levels
        - -- Ranges of possible logical states
            - --- Number of possible readiness levels
    - Physical
        - -- Operable Environments
            - --- Acceptable temperature and pressure ranges
            - --- Permissible mediums (water, land, air, space)
        - -- Inherent Capabilities
            - --- Speed, bandwidth, and frequency range
            - --- Memory capacity
            - --- Lifting capacity
            - --- Service features
            - --- Weapons accuracy and yield
            - --- Endurance ranges

TABLE 5

EXAMPLES OF ENTITY RELATIONSHIP MEASURES

THESE ARE MEASURES THAT DESCRIBE THE INTERNAL,
EXTERNAL, AND ENVIRONMENTAL ENTITY RELATIONSHIPS
AT ANY GIVEN INSTANT IN TIME

PHYSICAL RELATIONSHIPS

-- Distances between entities or systems
-- Numbers and types of entities in system
-- Physical interoperability between entities

ORGANIZATIONAL RELATIONSHIPS

-- Superior, subordinate, and peer relationships
-- Span of control and responsibility
-- Levels of control and responsibility
-- Types of control and responsibility

STATE RELATIONSHIPS

-- Hostile, friendly, neutral
-- Associated, not associated
-- Ignored, monitored, interacting

RELATIONSHIP POTENTIALS

-- Mutual operability potentials
-- Combined availability potentials

Process measures can be divided into two major subdivisions: ones that are systems-oriented and those that are mission-oriented. These two divisions of can be further subdivided as shown in Figure 3.12. This figure shows that system-oriented measures can be classified as either internal or external interaction measures and that mission-oriented measures can be classified as follows:

1. Supermission measures

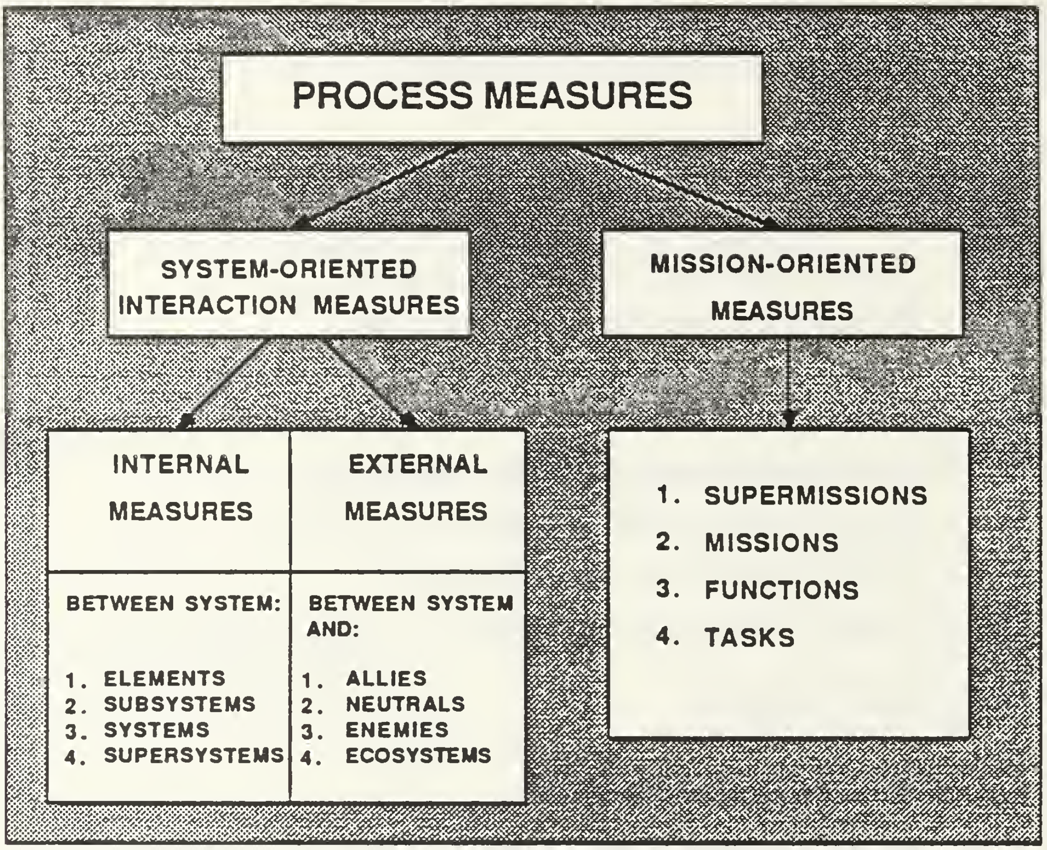


Figure 3.12 Process Measures

2. Mission measures
3. Function measures
4. Task measures

In addition, Figure 3.12 shows that the system-oriented measures can be further decomposed into a hierarchical classification scheme. For example, this figure shows that internal system-oriented measures can be classified by the highest level of internal system they are interacting with, whether an element, subsystem, system, or supersystem.[12]

This figure also shows how the external system-oriented interaction measures can be further decomposed. These measures can be classified as those that occur between the system and its allies, neutrals, enemies, and ecosystem.

System-oriented interaction measures are distinguished from mission-oriented measures in that the former are identified through their association with physical system boundaries, whereas the latter are identified through their association with process boundaries. Hence, system-oriented interaction measures are used to describe activities within or between systems and can be independent of any specific mission. The mission-oriented measures must describe some aspect of mission performance.

Many system-oriented interaction measures can become mission-oriented measures if they become associated with a particular supermission, mission, function, or task. All internal system-oriented measures can also be classified as at least one form of mission-oriented measure, as long as some scenario is provided. Frequently, one interaction process can affect several different mission-related objectives, so a measure associated with the one interaction process may contribute to several mission-oriented measures.

Mission-oriented measures are defined as those that assess how interaction processes affect the mission-related objectives of the systems of primary interest within the context of scenario. Supermission measures are those that assess how interaction processes affect the mission-related objectives of supersystems. The remaining three types of mission-oriented measures assess how the mission, function, or task objectives of the system of primary interest are being affected by internal and external interaction processes.

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[12] For the purposes of this thesis, systems are either subsets of, or direct supporters to, supersystems. A system can be subordinate to several supersystems. For example, within organizations, a branch is both subordinate to a division, which is in turn subordinate to a directorate. Similarly, a squadron can be subordinate to a group, which is subordinate to a wing, which is subordinate to a major command within a uniformed service as well as an operational command (e.g., a unified or specified command) and frequently a combined command. And finally, a command and control system can support several forces and command centers, although it may not be organizationally subordinate to these systems which are supported. Hence, there can be numerous levels and types of supersystems for a given system.

3. Implementation Measures

Whereas effectiveness measures are primarily concerned with describing how well alternative solutions address external threats or challenges (as described earlier in this chapter), implementation measures look at what are the direct costs and resks assoceated with the given alternatives. For the purposes of this thesis, these implementation measures will fall into the following three broad categories.

1. Direct Risks Measures
2. Direct Costs Measures
3. Transition Measures

The above three general types of implementation measures are illustrated in Figure 3.13, and are adapted from some work conducted by R. Choisser [Ref. 20: pp. 32 - 38]. Each of these categories will be briefly described in the following paragraphs.

Direct risk measures are those that assess cost, schedule, and technical risks associated with the various alternatives. Cost, schedule, and technical risks are typically interrelated. If, for example, an alternative solution cannot be implemented within a specified time-frame, then significant additional monetary costs may be incurred. Significant additional monetary costs may also be incurred if the technology within a specified alternative is not fully developed and involves complex scientific or engineering requirements. Significant schedule delays can be caused by both cost and technical issues. These risk measures are called direct risks in that they do not assess political issues, such as social costs, ethics, popular support, etcetera.

Direct cost measures are those that assess the monetary and resource costs associated with the various alternatives. Monetary costs can involve any or all of the life-cycle monetary costs of the system, as listed in Figure 3.13. Resource costs include the manning, materials, and machines that are required to implement the various solutions. Implementation costs are direct costs, in that they only reflect costs associated with the implementation of the system, not those associated with benefits that are lost with the adoption of various alternatives.

Transition costs assess how the implementation of various alternatives would impact the ongoing objectives or capabilities that the alternatives are supposed to facilitate. For example, if a new computer system is desired to improve the air defense system's capabilities, the implementation of this system may require significant temporary reductions in the capabilites of the system while old equipment is being removed and the new is being installed. Another example is the effect of a policy

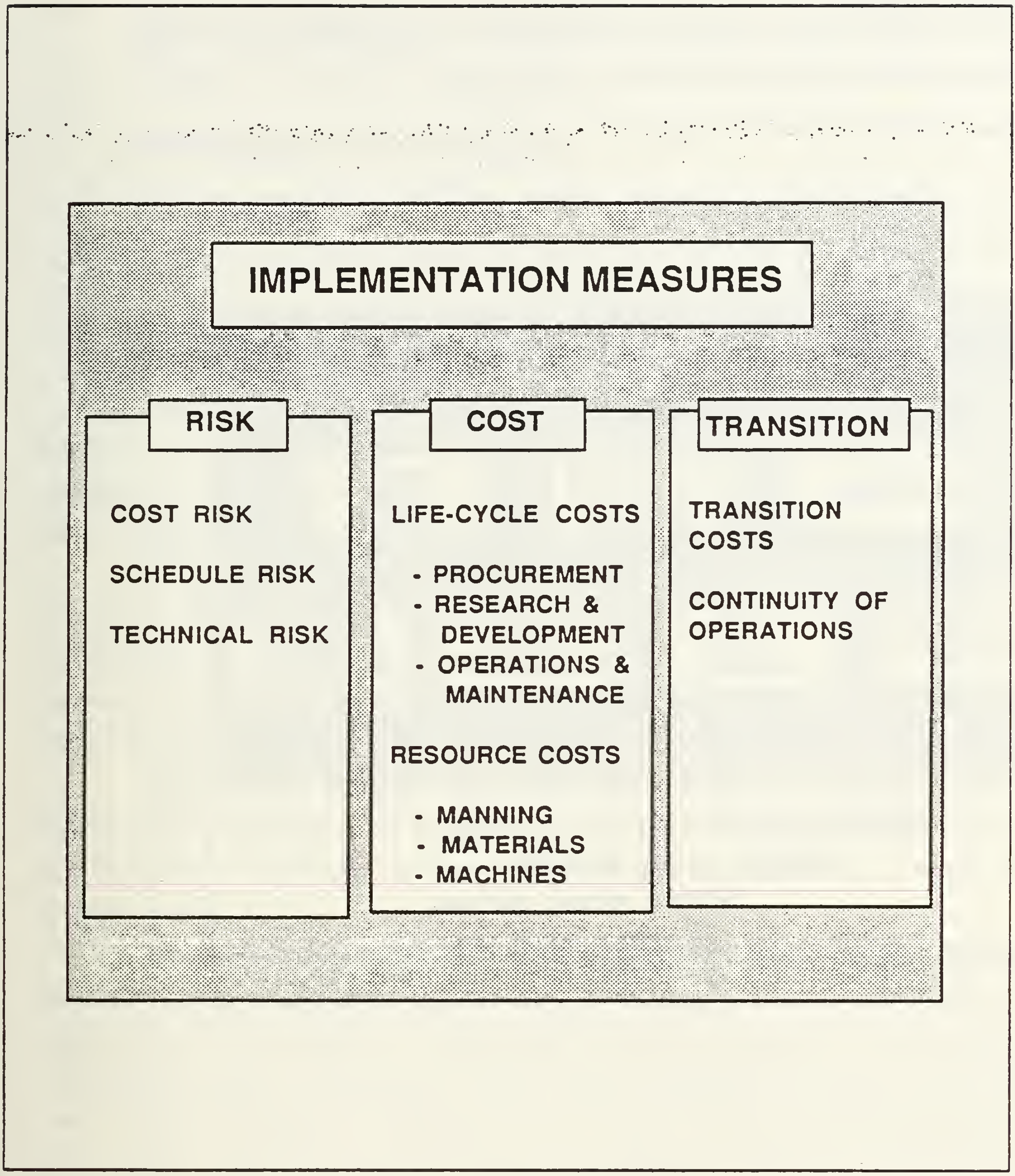


Figure 3.13 Examples of Implementation Measures

change. For example, the current reorganizaion of the Joint Chiefs of Staff is expected to yield some excellent long term benefits; however, in the short term, it may cause some difficulties in meeting the normal mission requirements because of the added transition responsibilities.

4. Political Measures

Political measures can be classified according to seven general areas. These seven areas are listed below and are illustrated if Figure 3.14.

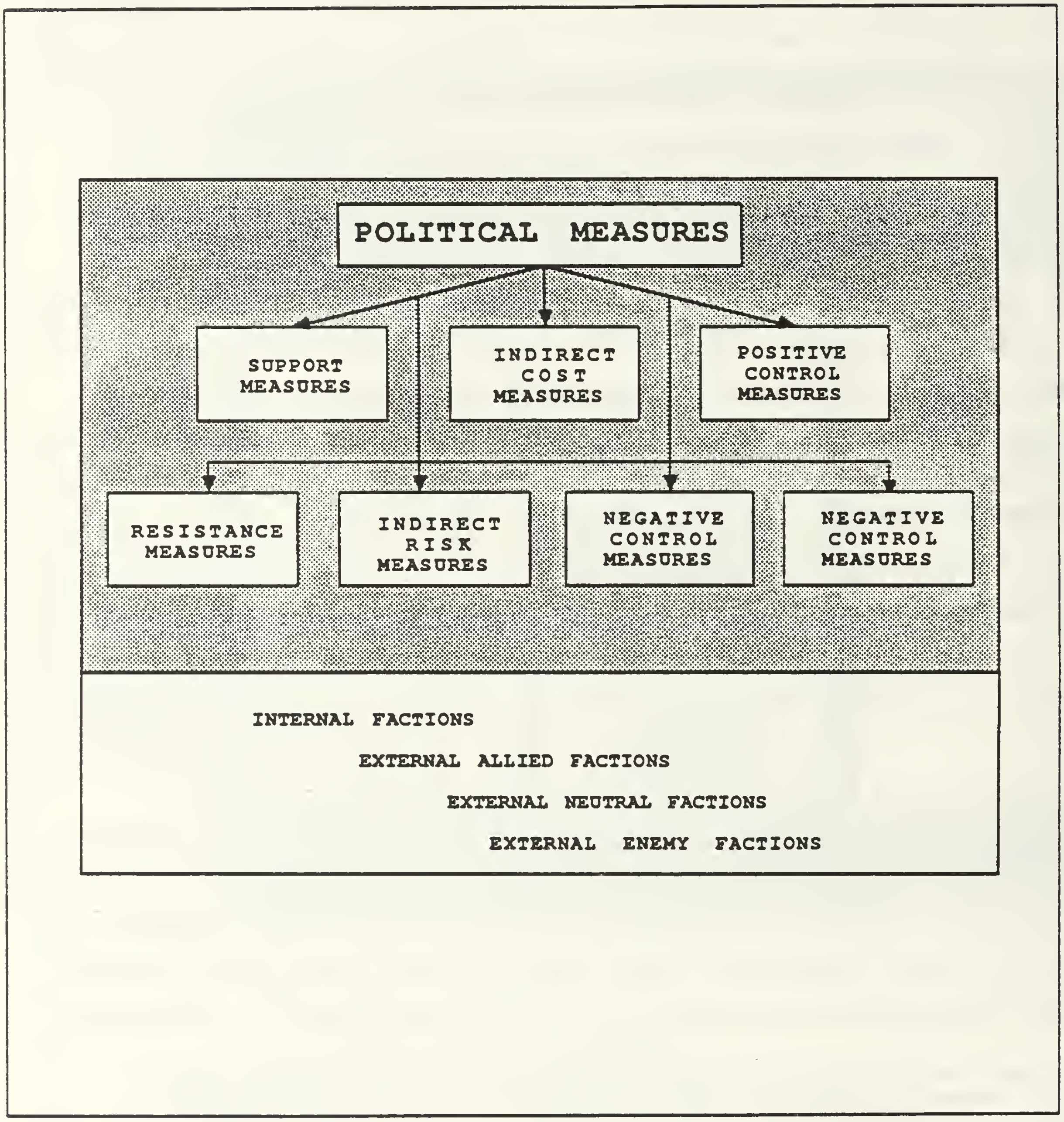


Figure 3.14 The Categories of Political Measures

1. Measures that assess the support that is required from various factions to implement or maintain a given course of action.

2. Measures that assess the resistance that is expected from various factions during the implementation or maintenance of a given course of action.
3. Measures that assess the indirect risks to various factions associated with the implementation of various alternatives.
4. Measures that assess the indirect costs to various factions associated with the implementation of various alternatives.
5. Measures that assess the indirect benefits associated with the implementation of various alternatives.
6. Measures that assess the positive control that may be exercised over various factions and that are associated with the alternatives being considered.
7. Measures which assess the aspects of negative control that may be exercised over various factions and that are associated with the alternatives being considered.

Support measures are those that assess the financial, political, legal, bureaucratic, etcetera support that is required from various factions to implement or maintain a policy. An example of a support measure would be the probability that the U.S. Congress will financially and politically back various alternatives.

Resistance measures are those that assess the nature and intensity of the opposition within various factions that may arise with the implementation or maintenance of alternatives. An example of this type of measure would be to assess how many people were likely to be arrested in a display of civil disobedience over the implementation of a given policy.

Indirect risk measures assess what are the risks to various factions if alternatives are implemented or maintained. An example of this type of measure would be: What is the probability that the President would be impeached if a secret policy becomes public?

The next two categories of political measures are those that involve indirect costs and benefits. Examples of these would be the costs (or benefits) associated with opportunities lost (or gained) to various factions given the adoption or maintenance of differing alternatves. An example of these types of measures would be: How many jobs or lives could expect to be gained or lost if various alternatives are implemented or maintained. Political risk and cost measures are similar except that the risk measures are assessing events that may or may not happen. Political costs measures are assessing events that are expected to occur, but are variable in the extent of the impacts.

The remaining two categories of political measures focus in on assessing how the adoption of various alternatives will effect the amount of control a given system has over other factions. Positive control measures assess how much influence a system has to get another system to do something. Examples of this include measures that assess such things as political leverage potential, (i.e., being able to get someone to do something, say, make concessions, in trade for something else that they desire) and political coercion potential, (i.e., the ability to get someone to do something to avoid unpleasant consequences).

Negative control measures can be used to assess how the various alternatives can influence another system or entities within a system to not take a course of action. The classic military example of a negative control measure would be one that assessed how likely an enemy would be deterred from initiating some form of conflict. Measures that assess deterrence, and failing that, escalation control, are not considered effectiveness measures in that effectiveness measures only assess how well particular systems perform missions under their relative control. In the case of the Strategic Air Command (SAC), for example, the SAC does not perform deterrence, but the SAC does perform missions that have a direct effect on deterrence. Since deterrence and escalation control are directly measurable only in the attitudes and actions of external parties, (i.e., the ones who are being deterred), these measures are outside the direct control (not influence) of the system of interest and are thus, for the purposes of this thesis, political measures.

5. Selecting Measures

The prior paragraphs within this section described the three major classes of measures, namely, effectiveness, implementation, and political measures. These prior paragraphs also showed how these broad measures could be decomposed. This decomposition process could continue for some of these measures almost indefinitely. Fortunately, for most problems, the identification and decomposition of measures needs to only proceed down a few levels of increasing detail. This sections will describe some principles concerning which measures to select and how far one needs to decompose a set of measures.

a. Qualities in Measures

The following list of qualities desired in meaures were adapted from two sources: a report by Alphatech corporation, entitled, *Systematic Evaluation of Command and Control Systems, Volume I*, [Ref. 21: pp. 13-16], and a Military Operations Research Society report, entitled *Command and Control Evaluation Workshop* [Ref. 22: pp. 6-12 to 6-15]. It is important to note that these qualities are goals to strive for, not destinations to reach. In practice, it is normally impossible to perfectly embody all of these qualities in a set of measures, since the systems they measure involve complex levels and types of interaction processes.

1. Relevance: The measures must describe aspects of the problem of interest that are relevant to helping the decision-makers solve their problem.
2. Minimality/Mutual Exclusiveness: Measures should be selected so that they are measuring different aspects of a problem, with as little overlap between measures as possible. Redundancy occurs within a given measurement level if one measure can be determined from other existing measures at the same level. Although seldom achievable, measures should be sought that are independent to the degree of being mutually exclusive. Minimality also requires only selecting enough measures to help answer the problem in question. Hence, the levels of decomposition are restricted to only those which are essential to answering the key questions of the decision-maker.
3. Completeness: The measures should encompass every major aspect of the problem of interest that are pertinent to identifying the most promising alternative solutions that are consistent with the analysis objectives. This quality is the balancing concept to that of minimality.
4. Simplicity: Measures should be easily understood by the users. Measures should be avoided that artificially aggregate many variables without a correspondence to aggregations that occur within the system of interest (e.g., aggregations that occur within the system of interest as a result of hierarchical structures or processes).
5. Precision: Measures should be clearly defined so that others can deduce the same values for the measures, given the required data.
6. Measurable: Measures must be able to have differing values that can be either objectively, or failing that, subjectively determined or postulated.
7. Realistic: Measures must be structured in such a way that they discriminate between alternatives as objectively and realistically as possible. Careful attention needs to be given to measures that require subjectively obtained data. Measures should reflect uncertainties in the data, as well as distributions in the outcomes.

b. Identifying and Selecting Measures

There are several principles that can be used to identify and select a set of measures that generally adhere to the desired qualities described in the prior subsection. Some of these principles will be described in the list that follows.

1. *Get oriented*: It is important that measures are developed that are relevant to the problem(s) of interest. Hence, the analyst should review the analysis objectives, desired states, and cases to be considered as a starting point. This will help the analyst to not get sidetracked from the major goals of the analysis.
2. *Use a top-down approach*: A top-down approach starts at the level of the supersystems supported. The top-level measures will normally need to reflect how the various measures impact the missions of the supersystems that are relevant to the problem in question. After measures have been developed that describe the relevant aspects of the supermissions supported, then lower-level measures can be developed that help to contribute to these upper level measures. These contributions do not necessarily mean that the measures identified need to directly aggregate up into the supermission measures, although this is frequently the case, but rather that these measures describe aspects and sensitivities within these upper-level measures.
3. *Identify the major interaction processes*: Identifying the major interaction processes within the hierachies of relevant systems, helps insure that the

measures that are developed are complete. This identification process should start at the level of the supersystems supported and then proceed downward as well as laterally to other interaction systems (see Figure 3.6). For example, if an analyst only reviews the mission statements of the supersytems supported or the mission statements of the systems of primary analytic interest, then the analysis may overlook important processes that are relevant to the problem.

4. *List measures that encompass differing analytic perspectives*: As discussed earlier in the this chapter, there are three basic perspectives through which systems can be viewed, namely, the technical, organizational, and personal perspectives. Measures can be developed that consider each of these perspectives. For example, a personal measure could be the likelihood of desertions and low morale, if, say, deployed military personnel think that their families are not being taken care of, especially if they feel their families are in danger.

5. *Decompose hierarchical measures based on essential fidelity*: Measures should only be decomposed as far as is required to insure that adequate fidelity levels are maintained. For example, if an upper-level measure only needs inputs that are correct to one decimal place, then developing a substructure of measures that produces ten decimal accuracy may be redundant.

I. ASSESSING MEASURES

> The first step is to measure whatever can be easily measured. This is OK as far as it goes. The second step is to disregard that which can't be measured or give it an arbitrary quantitative value. This is artificial and misleading. The third step is to presume that what can't be measured easily really isn't very important. This is blindness. The fourth step is to say what can't be easily measured really doesn't exist. This is suicide.

- Yankelovich [Ref. 2: pp. 17-18]

1. Section Overview and General Comments

This section will provide an overview of the general approaches that can be used to assess the measures that were identified in the prior module. This section is divided into two major parts. The first will discuss the quantitative method of assessing measures and the second will suggest some qualitative means for measures assessment. But before proceeding to these, the next few paragraphs will discuss some general aspects of measures assessment.

The quote that begins this section, brings out an important general point about assessing measures. That is: measures do not have to be easy to measure to be relevant. It is far more preferable to include all the measures that are relevant to a problem, even if they cannot be assessed accurately through the normal quantitative or qualitative means. Even if a measure cannot be accurately assessed, it can normally be addressed with some form of quantitative or qualitative bounding or valuation. Even then, some measures are still so difficult, say a theoretical nuclear weapons effect, that there is doubt beyond a simple order of magnitude. Yet these difficult measures can provide valuable insights into a problem and can be used to better assess the uncertainties within a given alternative or result.

The prior modules in the MAP identified the major cases that were to be examined as well as the measures that were of importance to the problem at hand. This present module seeks to determine the best ways to assess these measures. Hence, the first step within this module is that of developing a more refined case assessment approach. This approach can be multi-faceted, in that a variety of quantitative and qualitative techniques are available to the analyst. Some of these techniques will be described in the following paragraphs.

2. The Quantitative Assessment Approach

The quantitative approach for assessing measures within a specific case can be divided into six basic parts. They are:

1. Refining the problem formulation;
2. Building a model of the problem;
3. Collecting data to feed the model;
4. Exercising the model, and;
5. Validating the model,
6. Interpreting the results [Ref. 23: p. 3].

The refining of the problem formulation requires the answering of the following four questions. First, what are the specific measures that will be assessed in this case. Second, what specific models or type of models will be used to assess these measures. Third, what specific factors will act as constants and which ones will be allowed to vary. And fourth, what are the specific assumptions associated with the case.

Once a problem has been explicitly formulated, then the second step in the quantitative analysis process can occur, that of constructing or adapting existing models. For this thesis' purposes, a model will be broadly defined as an abstraction of reality that coalesces structures with processes, and the exercise of which can provide some useful insight into a problem of interest, typically through the assessing of measures associated with the model.

Models can be classified as to their purpose or according to their form. Some examples of the forms that models can take are: military field exercises, computer simulations, analytical representations, and, war games [Ref. 24: p. 10] The following quote points out one of the problems with models.

> In its most extreme form, modeling becomes an end rather than a means. The dedicated modeler reminds one of Pygmalion, the sculptor king of Greek mythology. He fashioned a beautiful statue of a girl and fell in live with it. Responding to his plea, the goddess Aphrodite brought the statue to life, and Pygmalion married his model. Today's modelers, mesmerized by the vast computer capacity, may also become wedded to their creations: the models become the reality. The computer's ability to handle large-scale models is confused with an ability to represent sociotechnical system complexity.

- H. L. Linstone [Ref. 2: p. 13]

The third step in the quantitative method of assessing measures is that of collecting data. Data collection normally is conducted concurrently with the construction or adaptation of a model, since the data is required to construct and drive the model (through data inputs). This activity typically includes some form of estimation or projection of parameters and variables through the use of such techniques as statistical estimation (e.g., sampling), statistical forecasting (e.g., exponential smoothing or regression models), or subjective estimation (e.g., historical data and polls) [Ref. 23: pp. 14, 16]

The fourth step in the quantitative measures assessment process is that of exercising the model(s) to produce results. Depending on the types of models used, this could, for example, involve placing observers at strategic points within a military exercise to make assessments or it could involve processing several computer simulation runs to produce results.

The fifth step in the quantitative measures assessment process is that of validating the model and its results. This validation can include such activities as verifying the veracity of the data bases used, verifying the results against expert opinion, and verifying the algorithms used within the models. This is a critical step in the quantitative assessment process, for if it is not accomplished, all of the results that are obtained are questionable at best.

The last step in the quantitative assessment process is that of interpreting the results. This is not the same as assessing the alternatives, as will be discussed in the next major section, but rather involves an objective assessment of what the results of the measures assessments mean (i.e., what can and cannot be safely deduced from the results).

One of the major activities that can occur at this stage of the measures assessment process is performing sensitivity analyses on the results. Sensitivity analysis is concerned with analyzing the nature of the results, for example, how stable are the results, what is their estimated mean and standard deviation, how much would the estimated parameters (i.e., constants) have to be in error before the results would change. [Ref. 23: p. 22]

3. Qualitative Assessment Approaches

Qualitative assessment approaches are similar to the quantitative approaches in many ways. For example, the problem formulation typically needs some level of refinement for each of the cases to be considered, data need to be collected, and the data typically need to be placed into some conceptual model (i.e., based on expert opinion, experience, etcetera). The results can then be verified and assessed. Some examples of the techniques that can be used when conducting a qualitative analysis are ones that use surveys, polls, historical reviews, interviews, social experiments, expert opinion, etcetera, both to collect data, as well as to verify and interpret the data collected.

Psuedo-quantitative, (or pseudo-qualitative, depending on your viewpoint), assessment techniques also exist for handling qualitative data. For example, fuzzy set theory has been developed to quantify qualitative terms so that they can be put into a computer input format. [Ref. 2: p. 17]

Qualitative assessments become very important when trying to assess questions with significant human decision-making interactions. For example, political and legal questions typically must be addressed with a qualitative form of measures assessment.

J. ASSESSING ALTERNATIVES

> Cost-benefit analysis and linear programming are typical of the search for the optimal solution. It usually comes as a shock to those nurtured on this paradigm that complex living systems have not organized themselves in accordance with such an optimization principle. As Holling notes, ecological systems sacrifice efficiency for resilience or trade avoidance of failure (the fail-safe strategy familiar to engineers) for survival of failure (safe-fail strategy). They seek to minimize the cost of failure rather than the likelihood of failure. They strive to maximize their options, rather than confine them by selecting the "best" one. They do not "manage" themselves by menacing themselves.

- H. L. Linstone [Ref. 2: p. 10]

1. General Remarks About Assessing Alternatives

The purpose of this section is to provide an overview of some of the principles and major methods for assessing alternatives. As the quote above would indicate, this may involve much more than finding what an analyst might feel is an "optimal" solution. This module makes up the sixth level of the MAP and seeks to integrate and organize the findings of the measures assessments that were performed in the prior level of the MAP.

Assessing alternatives within the context of the opposed sociotechnical systems typically requires the examination and valuation (for example, weighting) of multiple attributes. Multiple attributes are normally required because of the multiple goals (i.e., desired states) that are present with most decision-making situations.

This process of ranking alternatives based on multiple attributes is complicated for several reasons. One such reason is that the attributes that are being examined frequently are not similar in scale or type of measurement. For example, many attribute measures are necessarily qualitative rather than quantitative. The analyst and decision-makers are thus faced with the proverbial problem of comparing apples and oranges.

A second reason that the ranking process is complicated is that one alternative is frequently superior to another in some ways while inferior in others. Thus, the assessing of alternatives normally requires some concurrent scheme for ranking the value of divergent attributes and/or showing the trade-offs associated with adopting the various alternatives.

A third reason behind the difficulty in ranking alternatives results from the uncertainty inherent with the future. Typically, a broad range of possible future events could occur that would significantly influence the valuation of an alternative. Hence, much of the ranking process results from "best guesses" about the future.

A final reason that the assessment process is often difficult is because frequently there is more than one decision-maker involved with the problem being assessed, and each of these decision-makers may have different personal objectives -- hence, different criteria for assessing the various alternatives. Obtaining a consensus between the different decision-makers may be impossible, and hence, finding an alternative that will please (or at least minimally satisfy) these decision-makers may be quite a challenge.

Since it is difficult for decision-makers to consider every attribute and decision criteria associated with a problem all at once, strategies have been developed to logically break this assessment process down into manageable parts. These strategies fall into four broad categories. These are:

1. full dimensionality techniques;
2. single dimensionality techniques;
3. intermediate dimensionality techniques, and;
4. hybrids or combinations of the above techniques [Ref. 25: p. 29].

It is beyond the scope of this thesis to explain in detail the many aspects of each of the above methods. However, the following subsections will briefly explain the major characteristics of some of the most useful techniques.

Numerous references in the operations research discipline have good explanations of the techniques for assessing findings. If the reader desires to examine any of these techniques in more detail, the following works are recommended for their breadth in explaining the various methods.

1. The Joint Tactical Communications Office's Cost Effectiveness Program Plan (see the prior reference) provides an excellent synopsis, as well as some examples, of many of the techniques to be discussed below.
2. Hugh J. Miser's and Edward S. Quade's book titled, *Handbook of Systems Analysis*, provides one of the most up-to-date reviews of the many ranking methods currently in use. This reference has many examples and does a good job pointing out both the strengths and weaknesses of the various techniques.
3. R. L. Keeney's and H. Raiffa's work entitled, *Decisions with Multiple Objectives: Preference and Value Tradeoffs*, provides one of the best works for explaining the use of one index to rank alternatives, given many noncommensurable alternative attributes. Their work has laid the foundation for many of the modern concepts associated with decision analysis [Ref. 15: p. 143].
4. Several good works exist to help the analyst to develop a ranking scheme that avoids the strictly technological paradigms for ranking alternatives. Two of the most noteable of these are Graham T. Allison's, *Essence of Decision*, and Harold L. Linstone's *Multiple Perspectives for Decision Making*.

2. Full Dimensionality Techniques

Full dimensionality methods refer to evaluation approaches that separately and independently consider every attribute type within a set of alternative solutions. While full dimensionality techniques are normally used to determine if any of the alternatives can be eliminated, they can sometimes be used to yield preferred alternatives [Ref. 25: p. 30].

The requirement for independence within the full dimensionality technique requires that each attribute category be looked at and valued independently of any effects by any other different type of attribute that will be considered [Ref. 25: p. 30].

Hence, full dimensionality techniques do not use attribute weighting and aggregation schemes.

There are two primary full dimensionality techniques, namely, dominance testing and satisficing. Both of these techniques allow variables to be described in quantitative and/or qualitative terms. These two techniques will be described in more detail below.

a. Dominance Testing

Dominance testing is useful primarily as a means for reducing the number of alternatives under consideration. To use this method, an analyst or decision-maker compares each alternative to see if any one alternative completely dominates (i.e., has a more preferred attribute ranking) for every attribute considered. If so, the alternative that is dominated is eliminated. If one alternative does not completely dominate another alternative, yet has essentially the same or better marks for each of the attributes considered, then the essentially dominated alternative can also be eliminated. While dominance testing does not always provide a preferred alternative, it is an easily applied technique for reducing the number of alternatives considered [Ref. 25: p. 30].

b. Satisficing

Satisficing is a powerful technique for quickly identifying a "good enough" solution. Rather than seeking an alternative that optimizes the attainment of desired objectives, with satisficing, the decision-maker establishes lower bounds to objectives that must be met for an alternative to be considered acceptable. Once these lower bounds are set, then all of the "unacceptable" alternatives can be eliminated. If several alternatives have been identified as "good enough" by this satisficing method, then subsequent iterations can be performed, with new sets of minimum standards set by the decision-maker, to narrow the choice of alternatives down to one. Since analysts are frequently faced with severe time constraints in identifying a solution to an immediate problem, this technique can be quite useful. [Ref. 25: p. 30]

Like dominance testing, satisficing can be used in conjuction with other techniques. For example, after an acceptable satisficing alternative has been found, then another technique, such as some form of optimization, can be applied to whatever variables were left free within the range of acceptable solutions. [Ref. 15: p. 222]

3. Single Dimensionality Techniques

Single dimensionality techniques for ranking results attempt to reduce many attribute dimensions, whether quantitative or qualitative, into a single dimension for comparison purposes. Numerous techniques can be used to accomplish this, some of the most noteable of which are listed below:

1. Maximin, Maximax, Lexicography;
2. Additive Weighting and Effectiveness Indexing;
3. Cost-Benefit Analysis;
4. Cost-Effective Analysis;
5. Decision-Analysis
6. Fuzzy Set Analysis

a. Maximin and Minimin

Maximin (for payoffs) or minimax (for losses) are decision rules that reflect the attitudes of a pessimistic decision-maker. Maximin or minimax refer to decision rules that seek to identify the worst possible outcomes associated with various alternatives, and then which select the alternative that has the *best* of these worst possible outcomes. These decision rules are based on the philosophy that tries to make the best of what could be a bad situation. [Ref. 23: p. 656]

A minimin (for losses) or a maximax (for payoffs) decision rule reflects the attitude of an optimistic decision-maker. These decision rules would have the decision-maker pick an alternative which potentially is the minimum cost option (for minimin), regardless of the whether the cost risks associated with this option are far in access of another alternative slightly more expensive option. [Ref. 23: p. 656]

These two classes of single dimensionality ranking techniques, (i.e., maximin, minimin), will not be described further, other than to to state that they each suffer from similar drawbacks and are constrained in that most decision applications do not involve a totally optimistic or pessimistic assessment environment. For example, each of these techniques requires a high degree of comparability between all attributes and can overlook or discard a superior alternative because it only considers one aspect of the problem and because of incompleteness within each technique [Ref. 25: p. 31]. In addition, these, and other similar decision rules, suffer because they are not able to use specified prior probabilities, which are frequently relevant to a problem [Ref. 23: p. 656].

b. Additive Weighting and Effectiveness Indexing

Additive weighting is a single dimensionality technique that can be used to rank alternatives that have attributes which are numerical and of comparable scale. This technique assigns weights to each attribute to reflect their relative importance.

These weights are then normalized so that they sum to a value of one. These normalized weights are then multiplied against the corresponding attribute values for a given alternative, the results of which are then summed over the alternative's attributes to yield a weighted average. After this procedure is done for each alternative, the alternative with the highest weighted average is selected. [Ref. 25: p. 32]

Although this method does not suffer from the problems of incompleteness associated with the previously discussed single dimensionality techniques, it does have its own drawbacks. For example, it cannot be used to assign weights to attributes, that, although numeric, are fundamentally incommensurate (e.g. overpressure hardness measured in pounds per square inch and endurance measured in days, weeks, months, etcetera). Even when the numerical attributes are comparable, assigning weights tends to be subjective and can lack credibility. Achieving agreement between differing decision-makers about the relative importance of attributes (in an absolute sense) may be very difficult. [Ref. 19: p. 2]

The effectiveness indexing technique is similar to the additive weighting method described above, except that it uses weights in a functional form, rather that just a summation operation. This technique works to fit a function (i.e. any mathmatical operation defined in terms of the system's attributes) to the system under consideration. This method, like additive weighting, is limited in its usefulness to problems where the attributes are numerical and comparable. [Ref. 25: p. 32]

c. Cost-Benefit Analysis

The cost-benefit criterion is a single dimensionality technique which seeks to optimize or maximize the value of all benefits minus that of all costs, subject to the specified constraints [Ref. 15: pp. 44-45]. Risks can be considered as costs in this form of ranking technique in that one can often evaluate how much one is willing to pay to reduce or avoid risks [Ref. 15: p. 224].

In using this approach, consequences, whether benefit or cost, are converted by some means into monetary units. These monetary units are then summed, and the overall costs are subtracted from the overall benefits. The alternatives are then rank ordered by which alternative yields the highest excess of benefits over costs [Ref. 15: p. 224].

When using the cost-benefit criterion, analysts first identify all of the consequences associated with adopting or implementing each alternative for all future time, and then determine the monetary benefits and costs along with their associated probabilities of occurrence. The analyst then multiplies each monetary cost or benefit by the respective probabilities of occurrence to determine the expected gains or losses. Discount rates are then determined (i.e., assumed) and are applied against the future costs and benefits to obtain their present value. [Ref. 15: p. 225]

Although the cost-benefit approach is a very common criterion for evaluating public decisions [Ref. 15: p. 142], it suffers from many drawbacks. One major problem is that of how to translate consequences into monetary terms. Translating effects into monetary terms is often difficult, and always subject to question. Some effects are near to impossible to monetarily quantify. For example, how does one quantify in monetary terms the social effects of pollution or the effect on deterrence of a national civil defense program. Another drawback of the cost-benefit criterion occurs because of the many hidden assumptions within the computation. For example, how should the analyst choose an unbiased discount rate? An analyst advocating a program with a high front-end cost but a possible large long term benefit, would probably select a discount rate that would not significantly detract from the weight of future benefits. [Ref. 15: p. 225]

d. Cost-Effectiveness Analysis

The cost-effectiveness criterion is a single dimensionality technique where alternatives are evaluated by either holding the cost constant and ranking alternatives by their relative effectiveness or by holding the effectiveness constant and ranking the alternatives by their relative costs. This form of cost-effectivenss analysis serves as a powerful decision aid. For example, if a cost is provided as a given, the ranking analysis can proceed along the lines of optimizing the effectiveness. Unfortunately, the cost or effectiveness criteria are typically not inflexible, and hence cannot be provided as givens. This flexibility complicates the analysis process considerably. When this is the case, the cost versus effectiveness of each alternative is often plotted on a two dimensional plane for comparison analysis both between alternatives and within any selected alternative. [Ref. 15: p. 227]

The cost-effectiveness criterion is one of the most commonly used methods for ranking alternatives within the systems analysis community. And while performing a cost-effectiveness analysis normally yields useful information, its overall usefulness in definitively ranking alternatives is limited by several factors. For example, cost-effectiveness analysis is most useful as a ranking technique when there is only one dominant objective or goal that can be used to evaluate effectiveness [Ref. 15: p. 142].

When other objectives and goals are also significant to the ranking of alternatives, then the technique yields less than definitive information [Ref. 15: p. 228]. Other limiting factors will be briefly discussed in the following paragraphs.

A second limitation with the cost-effectiveness criterion arises because it only views costs that are directly associated with developing, implementing, and maintaining an alternative. These costs can include such things as money, resources, time, and manpower, yet they do not normally include important indirect costs. These indirect costs are those that involve any penalties or losses that accompany a given alternative that adversely impact the system of interest but are not included in the direct costs. These indirect costs are sometimes termed spillover cost effects. [Ref. 15: pp. 228-229]

e. *Decision Analysis*

Decision analysis represents a large body of single dimensionality techniques that attempt to rank alternatives by modeling the values or preferences of the pertinent decision-maker(s). The purpose of this modeling effort is to predict what the decision-makers choices would be, given that the decision-maker was able to consider all of the alternatives and their respective attributes as well as their consequences. [Ref. 15: p. 229]

Decision analysis has grown out of several long-standing disciplines. Some of these are subjective probability theory, utility theory, decision theory, and psychological methods for gathering value judgments from people. Whereas most of the applications for decision analysis have occurred with management problems in the civil sector, decision analysis is now also being used more within the military community to decide between competing alternatives. [Ref. 19: p. 5]

Decision analysis attempts to overcome one of the major disadvantages of the classical cost-effectiveness criterion: how to rank alternatives where effectiveness is multi-faceted rather than dominated by one factor. Decision analysis gets around many of the problems associated with classical cost-effectiveness analysis by developing a more pragmatic method of assigning weights to the various effectiveness dimensions. [Ref. 19: pp. 1,2] Whereas cost-effectiveness analysis assigns weights on the basis of a subjective assessment of the relative overall (absolute) importance of the differing attribute dimensions, the decision analysis approach assigns weights to the various attributes on the basis of their relative value as *discriminators* between the alternatives, not their absolute value in a global sense [Ref. 19: p. 10].

One specific technique within decision analysis is to develop a multiattribute utility model as a means to rank alternatives. Numerous examples exist where a multiattribute utility model was developed to help rank alternatives. Two examples of where these models have been implemented with computerized near-real-time displays, interactive software, and hard copy records capabilities are listed below:

1. The Worldwide Digital System Architecture Study used a computerized analysis model to help rank its competing system alternatives. This application of multiattribute utility theory is described in the Defense Management Journal's article, *An aid for evaluators of system design alternatives*, by Dennis M. Buede and Robert W. Choisser (Second Quarter, 1984) and is also described in the reference from the previous paragraph. [Ref. 20: pp. 32-38]
2. Another generic decision analysis model exists at the Defense Communications Agency, called the ISMAUT (Imprecisely Specified Multiattribute Utitility Theory) model, which allows the user to use natural language inputs to score and assess alternatives.

The disadvantages to the decision analysis approach are those that are inherent to any single dimensionality approach. One problem is that of the information that is suppressed during the aggregation process (although this problem can be largely overcome by expanding the dimensionality through going back to the previous steps in the process). Another problem is that of the imprecision inherent with the assessment of utility and weights between incommensurate variables. And finally, producing a value function that resembles that of decision-makers can be extremely difficult, time-consuming, or impossible, especially if there is marked disaggreement between decision-makers. On the other hand, using a decision analysis tool can also, at times, be a vehicle to help identify and resolve conflicts between decision-makers when used with a decision arbitrator or facilitator. [Ref. 15: p. 230]

f. Fuzzy Set Analysis

Another technique that may prove very useful in ranking alternatives is that of fuzzy set analysis. Dr. John Dockery of the Office of the Joint Chiefs of Staff (OJCS/J-6) has been one of the strongest advocates of developing and applying this mathematical approach to military assessments. To date, fuzzy set analysis, as used within such computer programs as the OJCS sponsored Performance Assessment Roll-Up Program, have been very helpful is eliciting expert opinion for the ranking of deficiencies within complex frameworks. Research is ongoing to rank the remedies to a system's problems by linking them to the deficiencies that have been identified and ranked by fuzzy set analysis. [Ref. 26: pp. 1-54]

Some of the strengths of the fuzzy set approach are that it does not require consensus between decision-makers, that it allows for information quality assessments such as stating how strongly one believes a certain thing to be true, and it provides some very powerful tools for sensitivity assessments. Another strength resides in its ability to link assessment information together. For example, it can link capabilities to deficiencies to solution alternatives, etcetera. Overall, fuzzy set theory, along with its new applications, provide mathematically rigorous tools for dealing with some of the uncertainty, complexity, and lack of consensus inherent in many decision-making situations. [Ref. 26: pp. 41-51]

4. Intermediate Dimensionality Techniques

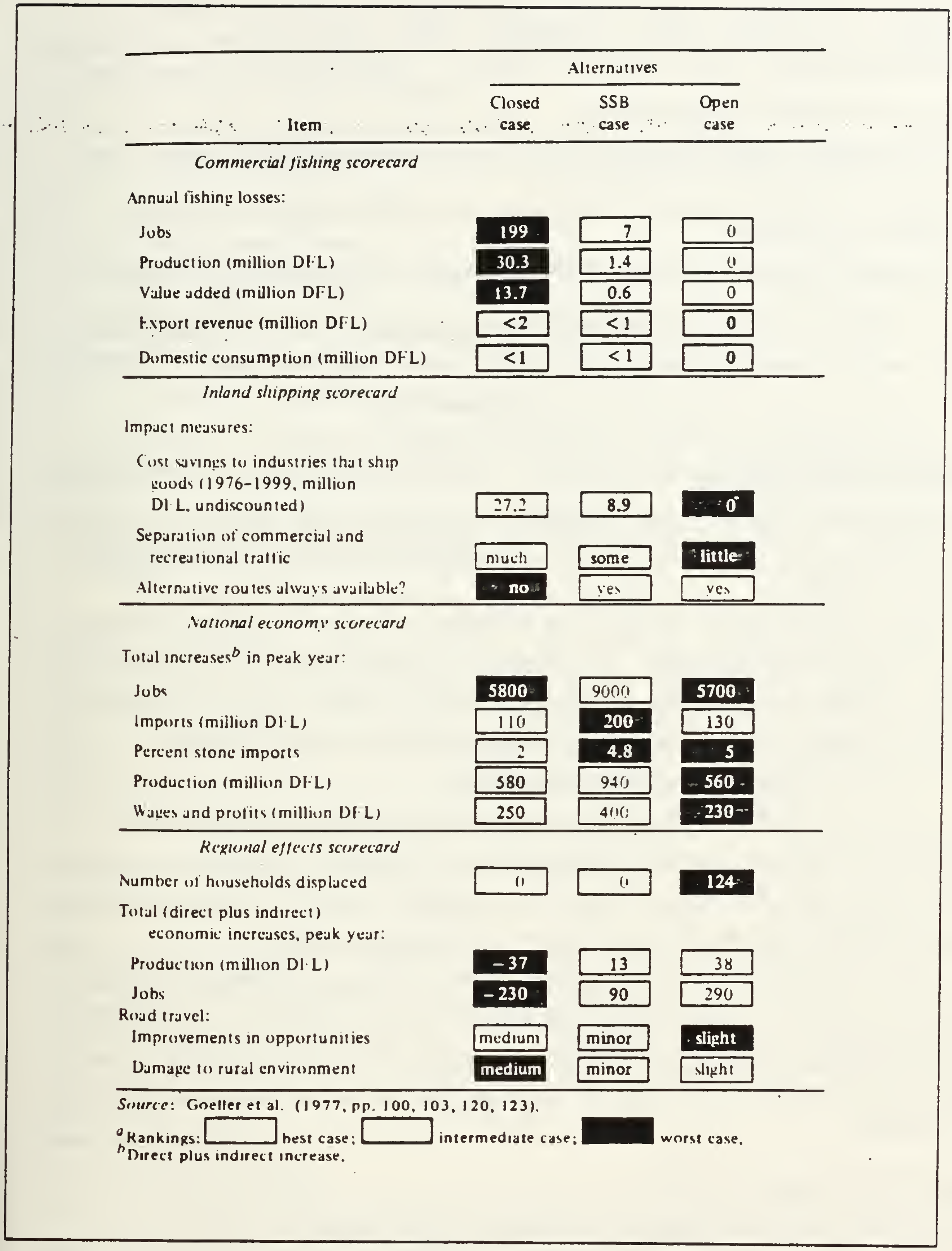
The next major method of evaluating alternatives is by using intermediate dimensionality techniques. These methods consider more than a single attribute dimension but do not consider every dimension. There are many intermediate dimensionality techniques, such as trade-off and nonmetric scaling analysis, but for the purposes of this thesis, only the most flexible and widely recognized one, scorecard analysis, will be discussed.

a. Scorecard Analysis

Scorecard analysis is an intermediate dimensionality technique that uses two-dimensional arrays or matrices to present the analysis results. Bruce Goeller, of the Rand Corporation, has been one of the prime advocates of using this form of presenting results versus that of cost-benefit, cost-effectiveness, or other single dimensionality approaches. Goeller is the one who has popularized the term *scorecard* to mean the two dimensional array presentation technique to be described in the following paragraphs. [Ref. 15: p. 231]

In using the scorecard approach, a table is constructed where each row represents a category of impact or generic attribute and each column represents a different alternative. The specific values for a given row-category are displayed in natural units under the respective alternative columns. These natural language units appear as numbers or words that explain the size and direction of a particular impact or attribute in absolute terms. See Figure 3.15 for some examples of a real-world use of scorcards. This figure is taken out of the book, *Handbook for Systems Analysis*, and were used in an assessment conducted by Goeller and others called the Policy Analysis of the Oosterschelde (POLANO) project. This project had a goal of determining how best to protect a large estuary from flooding. [Ref. 15: p. 81]

The scorecard approach then adds value judgments to each row by comparing the utility of the various alternative values within a given row. This can



	Alternatives		
Item	Closed case	SSB case	Open case
Commercial fishing scorecard			
Annual fishing losses:			
Jobs	199	7	0
Production (million DFL)	30.3	1.4	0
Value added (million DFL)	13.7	0.6	0
Export revenue (million DFL)	<2	<1	0
Domestic consumption (million DFL)	<1	<1	0
Inland shipping scorecard			
Impact measures:			
Cost savings to industries that ship goods (1976–1999, million DFL, undiscounted)	27.2	8.9	0
Separation of commercial and recreational traffic	much	some	little
Alternative routes always available?	no	yes	yes
National economy scorecard			
Total increases^b in peak year:			
Jobs	5800	9000	5700
Imports (million DFL)	110	200	130
Percent stone imports	2	4.8	5
Production (million DFL)	580	940	560
Wages and profits (million DFL)	250	400	230
Regional effects scorecard			
Number of households displaced	0	0	124
Total (direct plus indirect) economic increases, peak year:			
Production (million DFL)	−37	13	38
Jobs	−230	90	290
Road travel:			
Improvements in opportunities	medium	minor	slight
Damage to rural environment	medium	minor	slight

Source: Goeller et al. (1977, pp. 100, 103, 120, 123).

[a] Rankings: ☐ best case; ☐ intermediate case; ■ worst case.

[b] Direct plus indirect increase.

Figure 3.15 Several Scorecards from the POLANO Project

either be done by shading, as is done in the POLANO figures, or it can be done with color schemes (the preferred method, if possible). These rankings within a row are conducted independently of any other row. [Ref. 15: p. 98] Some of the advantages of the scorecard approach are listed below.

1. It is normally easily understood by all of the decision-makers since it uses natural units and limited aggregation.
2. It is a convenient vehicle for discussing trade-offs and how to improve a particular alternative.
3. It is explicit in that it directly illustrates qualitative and quantitative impacts. [Ref. 15: p. 232]

While the scorecard approach offers many adantages with its flexibility and its appeal based on ease of understanding, it does have some drawbacks. Some of these disadvantages of the scorecard approach are listed below.

1. Too much information may be presented for the decision-makers to assess all at once. The problem can then become to complex to arrive at a convergence between decision-makers.
2. Too little information may be presented. For example, since not every impact or attribute would normally be displayed, the selection of impacts or attributes to be displayed may leave out a variable important to a decision-maker. [Ref. 15: p. 233]

Another interesting aspect of the scorecard is that it can display variable values within each attribute column. It is beyond the scope of this thesis to discuss this aspect of scorecards other than to say that Miser's and Quade's book, *Handbook for Systems Analysis*, provides some excellent examples of this on pages 232-238.

5. Conclusions Concerning Assessing Alternatives

All of the methods that have been described in this section on the assessing of alternatives have their own strengths and weaknesses. The nature of the problem and the time and resources available for the analysis should dictate the choice of which assessment techniques are used for any given decision-making situation.

It is recommended that if an analysis team is using a single-dimensionality technique as the primary means for assessing alternatives, that additional intermediate and full dimensionality techniques be used as back-up support. This is particularly true if several decision-makers are involved and if the problem has several incommensurate decision variables.

K. RESULTS PRESENTATION

The results presentation module is perhaps the most important in the analysis process. A poor presentation can effectually negate the impact of untold hours of accurate analysis. Alternately stated, a presentation may well be worth a thousand analyst-hours. This section will briefly examine five activities that occur during the results presentation process, namely:

1. Presentation objectives determination;
2. Audience analysis;
3. Presentation development;
4. Interim presentations;
5. Finished presentations.

Figure 3.16 illustrates the five stages of activities within the results presentation process. This figure serves as a visual overview for the explanation that follows.

1. Presentation Objectives Determination

The first step in the results presentation process is to identify what the objectives of a given presentation are. These objectives may be dependent on the following: the stage of the analysis (e.g., interim results versus final results), the audience, the analysis objectives, etcetera.

In general, these objectives can be grouped under two major headings: external and internal. External objectives result from the analysis team's efforts to faithfully support the decision-maker(s) who have a need for the analysis. These objectives try to respond to the needs and legitimate expectations of the key decision-makers. Internal objectives reflect more of the goals and expectations of those involved in the analysis process, as well as their associated organizations.

The primary goals and their relative importance for a given presentation should be communicated as explicitly as possible to the presentation development team. An explicit statement of the goals can greatly help to focus the efforts of the team, as well as reducing the frustration that occurs when time is wasted in the pursuit of lesser or conflicting objectives. For example, many analysts tend to love details and technical explanation of the means of generating results, while many decision-makers do not. A lot of time can be wasted by generating too technical or too detailed or too long of a presentation, when a summarized version is what the decision-maker eventually demands.

2. Audience Analysis

A second activity shoud be conducted while the presentation objectives are being determined. This is the audience analysis. This analysis should answer the following questions:

1. Who (people, organizations, etc.) will be reviewing the results?

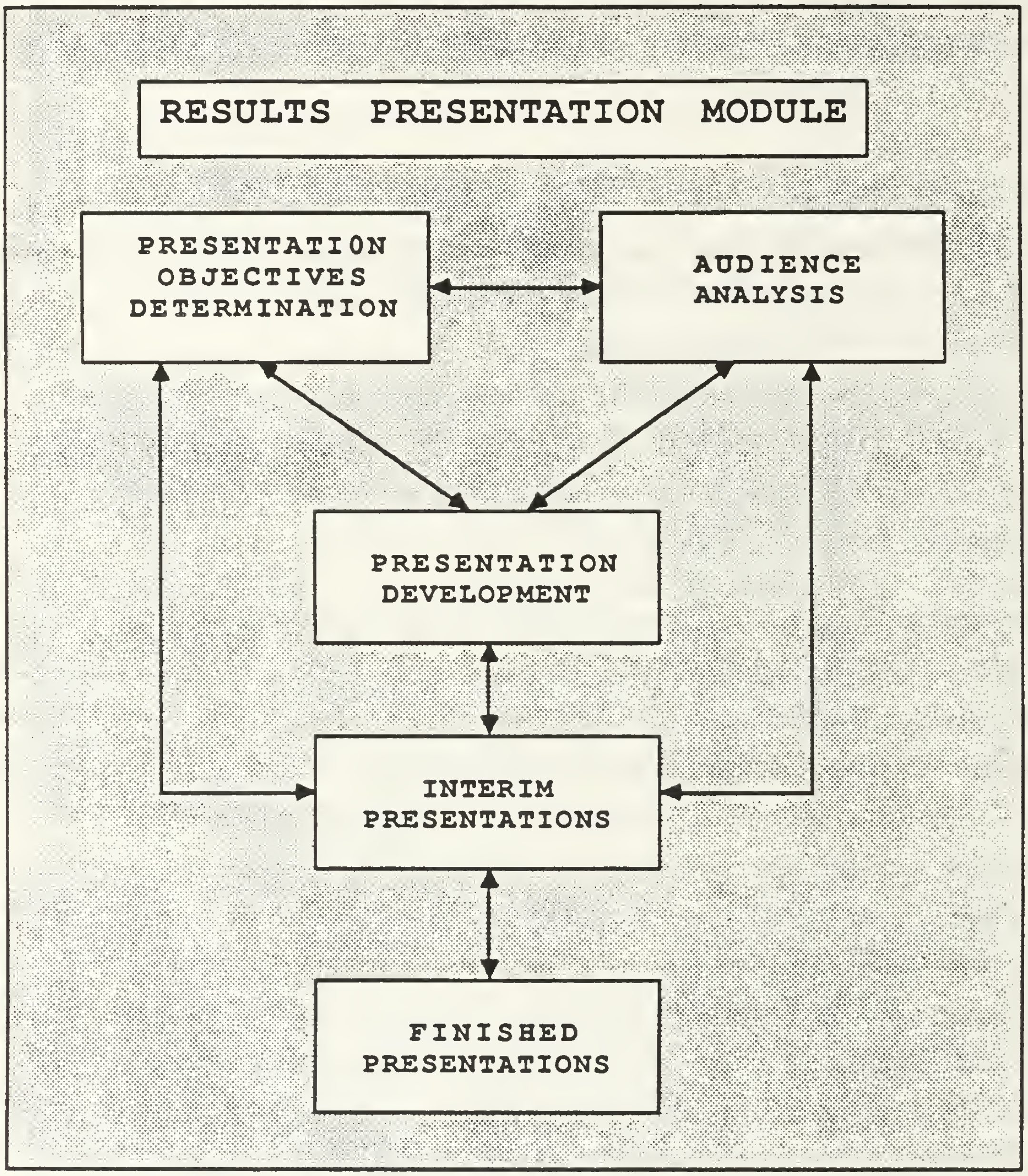


Figure 3.16 The Results Presentation Module

2. What will they be sensitive to?
3. How may they be expected to respond to the results and their presentation?

Several benefits are derived from answering the above audience analysis questions. In fact, this analysis may prove essential to the development of effective presentation objectives. Some of the key presentation objectives may be stated in terms that directly relate to the audience. For instance, an objective may be to convince Decision-maker A of the need to change a policy, while being prepared to recommend two new alternative policies that would alleviate the problem and be acceptable to Decision-makers A, B, and C.

An audience analysis helps to insure that the presentation is responsive to the various sensitivities represented within an audience. This analysis helps lay the groundwork for the next stage of the results presentation process, that of the presentation development.

3. Presentation Development

The presentation development activity merges the prior two activities in the following way. By reviewing the presentation objectives and the audience analysis, the presentation development activity uses this information, along with its understanding of the tools of the presentation trade, to determine what are the best means to achieve the objectives given the audience.

There are innumerable methods of presenting results. These range from a variety of written reports and papers, to briefings, to demonstrations.

Just as there are numerous ways to present results, there are just as many ways to develop these presentations. If a report or briefing is very large or complex and has a strong graphics orientation, the analysis team may want to consider using a picture wall or room in developing the structure of the presentation format. In one application that the author was involved with, a picture room was used very successfully in developing the structure for a very complex report. The analysis team would meet regularly to look over the results on the charts and to see the flow of the evolving document. Graphs and figures that were only notional were held up with red pins, ones with partial data were held up with yellow pins, and ones that had complete data were held up with green pins. As different levels of the analysis management viewed the developing report, they were able to "walk through" the report and make adjustments to the format, etcetera, relatively easily. The reviews by senior analysts and decision-makers were in one sense a step in the presentation development process, but they were also a form of interim results presentation. The next section will discuss the importance of interim presentation activities.

4. Interim and Finished Presentations

Interim presentations can serve several important purposes. For example, they can act as an intermediate check on the analysis results to see if the results are defensible and reasonable. If initial results are based on models or situations or phenomenology that is not completely mastered by the analysis team, these interim briefing can seve to "benchmark" the results against the critical eyes of recognized experts. If possible, it is a good idea to try to get the recognized experts to formally validate an analysis algorithm and initial results, on a few cases, before expending numerous analyst hours to examine all cases. In one case that the author was involved with, nearly three analyst staff months were rendered useless because of waiting to present interim results to the experts until after numerous cases had been run verses doing it after the first few cases.

Interim presentations also serve the purpose of allowing the senior analysts, staffs, etcetera, to adjust the format, scope, and the general direction of an analysis. An example of this was presented in the previous section where a picture room was used for this purpose. The picture room served as a briefing room when senior analysts and staff of the tasker organization came to oversee the analysis process. As key analysts and staff personnel made adjustments to or approved the format and direction of any analysis during an interim presentation, they will share more ownership of the final product.

Other examples of interim presentation methods would include draft copies of reports that are sent out for comments, regular progress reports (e.g., monthly or weekly activity reports), and informal meetings to discuss results with those who would be affected by those results. Keeping key people informed about the progress of an analysis can prevent some unpleasant technical or political surprizes near the end of the analysis.

Finished results refers to results presentations that are approved for release as a completed action or that meet tasker requirements. They are the culmination of the analysis process.

L. CHAPTER SUMMARY

This chapter has provided the reader with a generic analysis framework called the Modular Analysis Process (MAP). The MAP was shown to have the following seven levels.

1. The first level was comprised of the Problem Formulation and Control Module. This module provided guidance to the analyst on how to determine the analysis objectives, how to characterize the problem, and how to formulate an initial analysis approach. This module stressed the importance of performing an initial assessment within the Problem Formulation stage of the analysis in order to validate the analysis approach selected. This module also stressed the importance of viewing problems from several perspectives, such as an organizational perspective and a personal perspective, in addition to the normal technological perspective.
2. The second level of the MAP was comprised of Modules which developed the desired states (i.e., objectives) associated with the problem of interest, as well as the scenarios and alternatives that were to be considered.
3. The third level of the MAP sought to integrate the activities of the prior level of the MAP. Specifically, this level developed, prioritized, and selected the cases that would be assessed later within the analysis process.
4. The fourth and fifth levels of the MAP developed the measures that would be used to assess the cases developed in the prior level. In addition, the fifth level provided several principles for performing quantitative and qualitative measures assessments.
5. The sixth level of the MAP was concerned with the assessing of the alternatives in light of the measures assessments that were made in the prior level. Three general classes of techniques were described for performing these assessments, namely, full dimensionality, single dimensionality, and finally, intermediate dimensionality techniques. It was recommended that more than one technique be used when possible, as each technique has its own strengths and weaknesses.
6. The last level of the MAP was concerned with the presenting of the results developed throughout the prior levels. Several suggestions were made concerning presentation techniques, such as the usefulness of a picture wall or room when complex graphics were needed. Finally, several results presentation principles were discussed, such as the importance of performing an audience analysis.

The last chapter in this thesis will apply portions of the MAP to a specific problem. This problem will examine the nature of command and control structure that is required to integrate the operations of several unified and specified commands within the context of global-scale warfare.

IV. THE GLOBAL SCALE WARFARE (SUPERCINC) C2 PROBLEM

A. CHAPTER OVERVIEW

This chapter will use selected modules within the Modular Analysis Process (MAP) (as developed in the prior chapters) to analyze a problem posed by the Office of the Deputy Assistant Secretary of Defense for C3. While the long title for this problem is the Command Structure for Global-Scale Warfare[13] the title that will be used throughout the remainder of this thesis is the SuperCINC problem [Ref. 27: p. 6].

This chapter will focus primarily on the first module of the MAP, namely the Problem Formulation and Control module. This module was explained in Chapter III of this thesis and is illustrated here once again for the reader's convenience. Other modules within the MAP will be visited as required during the execution of this first module.

B. DETERMINING THE ANALYSIS OBJECTIVES

1. Identifying the Decision-Makers

The first step in determining the analysis objectives, as described earlier in this thesis, is that of determining who are the supported decision-makers. For the SuperCINC problem it was found that there are several different decision-makers potentially supported, as will be described in the following paragraphs.

The first decision-maker supported is the problem poser. The SuperCINC problem was originally posed by Dr. Thomas P. Rona, who was at the time on the Deputy Assistant Secretary of Defense's (C3) staff. He is now serving as the Acting Deputy Director of the Office of Science and Technology Policy. Dr. Rona stated the main issue within this problem as follows:

> At this time, there is no satisfactory concept to provide for the C&C (command and control) support required to exercise operational[14] command responsibility

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[13] Global-scale warfare, for the purposes of this thesis, is defined as conventional and/or nuclear operations conducted by the United States, possibly in concert with its allies, directed concurrently against major enemy forces in more than one unified, specified, or joint task force commander's area of responsibility.

[14] Operational command is defined as "Those functions of command involving the composition of subordinate forces, the assignment of tasks, the designation of objectives and the authoritative direction necessary to accomplish the mission.

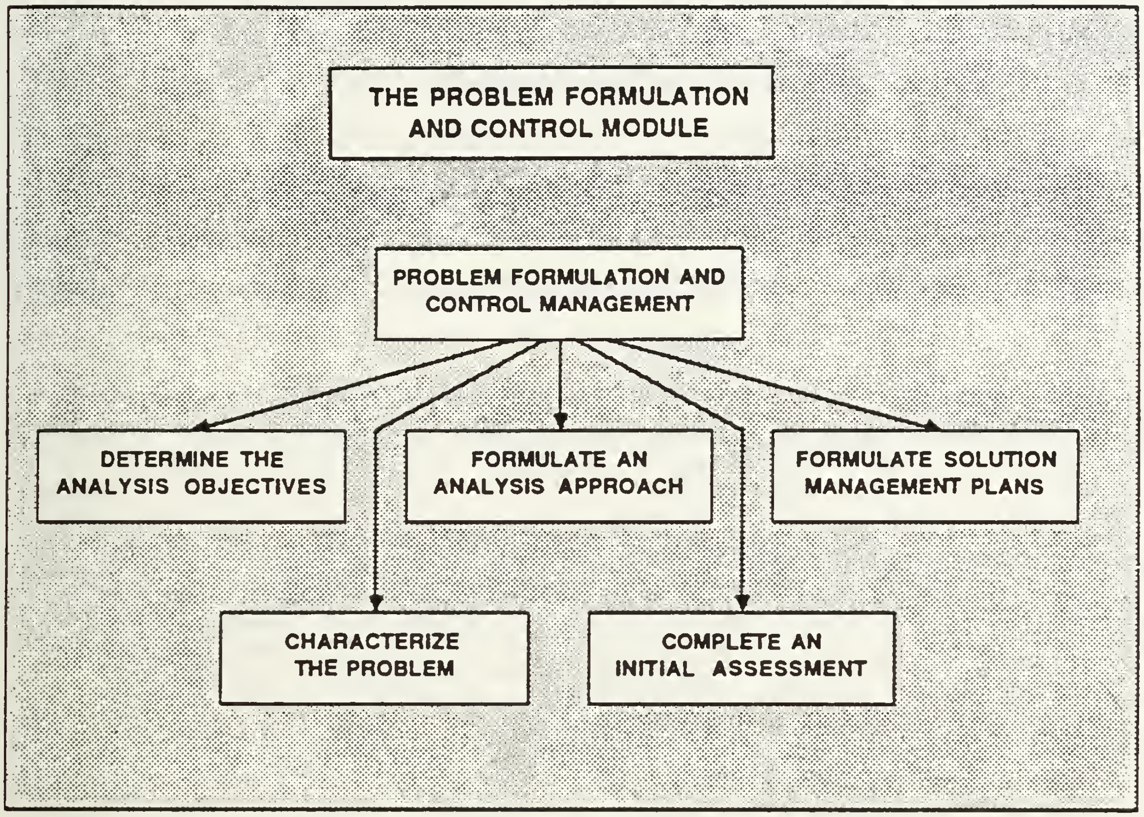
THE PROBLEM FORMULATION AND CONTROL MODULE
PROBLEM FORMULATION AND CONTROL MANAGEMENT
DETERMINE THE ANALYSIS OBJECTIVES
FORMULATE AN ANALYSIS APPROACH
FORMULATE SOLUTION MANAGEMENT PLANS
CHARACTERIZE THE PROBLEM
COMPLETE AN INITIAL ASSESSMENT

Figure 4.1 The Problem Formulation and Control Module

above the CINC level when operations involve the integrated activities of several CINCs. [Ref. 27: p. 6]

There are several other types of decision-makers who would be potentially involved with the SuperCINC problem. For example, the United Sates Congress would collectively act as a decision-maker if any significant changes were required to

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[Ref. 28: p. 263]

the structure of the military C2 system. In addition, the Executive and the Judicial branches of the government would also very likely be involved with any major reorganization. Below these national levels, there would also be a great many policy makers within the DoD that would be acting as decision-makers in regards to the SuperCINC problem. The highest decision-making body involved with this problem would ultimately be the United States populace.

2. Identifying the Decision-Makers' Analysis Objectives

The next step in this submodule is that of identifying what are the decision-makers' analysis objectives. To determine the decision-makers' objectives, it is essential to have some understanding of the decision-makers' view of the problem. The following paragraphs will explore how the SuperCINC problem is viewed by Dr. Rona and subsequently by the United States Congress.

In a memo written by Dr. Rona for the Deputy Assistant Secretary of Defense for C3, Dr. Rona provided the following background to the problem.

> The (C2) structure, when fully brought up to the level necessary to satisfy the design objectives, will be adequate to support operations that are essentially circumscribed within the responsibility of individual CINCs. It will not satisfy the operational needs of global-scale warfare (nuclear or other) when these involve operations that transcend the currently defined purviews of the Specified and Unified Commands. For instance, a large-scale nuclear conflict may involve, in a real-time operational sense, SAC, USSPACECOM, CINCEUR, CINCLANT, CINPAC, at least, and probably several others. [Ref. 27: p. 6]

Congressional statements that address the SuperCINC issues fall along the same lines as Dr. Rona's statements. For example, the Staff Report to the Committee on Armed Services, United States Senate, titled, *Defense Organization: the Need for Change*, makes several important observations that relate to the SuperCINC problem. These will be addressed in the following paragraphs.

The first problem area that is listed in the above referenced document is that of the limited mission integration of the overall defense effort. The report states that:

> Since the end of World War II, the central issue in proposals to reorganize the U.S. military establishment has been the extent to which the distinct military capabilities of the Army, Navy, Air Force, and Marine Corps need to be integrated to prepare for and conduct effective, joint military operations in times of war. . . . Mission integration, the ability of the Services to take unified action to discharge the major military missions of the United States, . . . was and remains the real goal of proposals to reorganize the U.S. military establishment. [Ref. 29: p. 77]

The Staff Report also pointed out the problems associated with the lack of unity of command at the highest military levels. For example, the following quote from former Secretary of Defense James R. Schlesinger was cited in the report:

> In all or our military institutions, the time-honored principle of 'unity of command' is inculcated. Yet at the national level it is firmly resisted and flagrantly violated. Unity of command is endorsed, if and only if, it applies at the Service level. The inevitable consequence is both the duplication of effort and the ultimate ambiguity of command. [Ref. 29: p. 319]

This report particularly emphasized the problem of the confused chain of command from the Commander in Chief (i.e., the President) to the oeperational commanders (i.e. the Commanders in Chief of the Unified and Specified commands). The report states the following about this major deficiency:

> There is considerable confusion over the roles of the Secretary of Defense and Joint Chiefs of Staff in the operational chain of command. As a result, the appropriate relationships between the operational commanders and those above them in the chain of command are very uncertain. There are two basis causes of this confusion: unclear statutes relating to the role to the Secretary of Defense in the chain of command and an ambiguous DoD directive relating to the role of the JCS. The chain of command is further confused by the de facto influence that individual Service Chiefs retain over the operational commands. [Ref. 29: p. 303]

Senator Gary Hart, co-founder of the Military Reform Caucus, has pointed out another important issue related to the SuperCINC problem. This problem involves the bureaucratic nature of our military establishment, especially at the levels above the unified and specified commanders in chief. The following quote from Senator Hart's book, *America Can Win*, illustrates this point.

> The resistance of bureaucracies to change brings us to the bottom line of military reform. The dominant characteristics of combat are uncertainty and rapid change. Bureaucracies deal very poorly with both. Our armed services today are bureaucracies. Hence, the organizational model of our armed forces is 'directly contradictory' to the nature of the environment in which they are supposed to operate. . . . This is the root reason why we cannot hope to achieve adequate military strength simply by spending more money, introducing more technology, or buying more weapons. . . . The bottom line of military reform, therefore, is and must be *abandoning the bureaucratic organizational model.* [Ref. 30: p. 243]

Given the above observations that pertain to the SuperCINC problem, the decision-makers' statement of the problem requiring analysis could be phrased: What changes are required to the military C2 system that will provide for the operational C2 capability required above the CINC level to effectively integrate the operations of the unified and specified commands within the context of global-scale warfare? Specific objectives for the analysis, which could be inferred from the above observations include:

1. What changes are required to the current National Military Command System (NMCS) and its supporting systems to effectively integrate the activities of several CINCs?
2. What changes are required to remove the ambiguity in the operational chain of command, particularly with regards to the Secretary of Defense, the Joint Chiefs of Staff, and the Service Chiefs?
3. What changes are required to ensure that the principle of unity of command is embodied within the C2 structure at the highest levels of the military establishment?
4. What adaptive structures should be introduced into the C2 system to replace the ponderous and ineffective bureaucratic military structures within the operational chain of command?

A second activity (among several mentioned in Chapter III of this thesis) associated with determining the decision-makers' analysis objectives is to survey what analysis approaches the decision-makers desire. Dr. Rona suggested performing at least the following two tasks. First, he suggested that nuclear and non-nuclear scenarios be developed that would require operational command responsibilities above the CINC level in order to integrate the activities between several CINCs. Second, he suggested that a survey be conducted of the existing concepts of military organization and their associated combat doctrines, particularly those concerned with global-scale conflicts. He suggested that alternatives to these concepts be developed and that their advantages and disadvantages be explicitly expressed.

3. Determining How the Analysis Should Support the Decision-Makers

The last step in determining the analysis objectives is assessing how the analysis should support the decision-makers. For the purposes of this thesis, the objective for this analysis is to lay the groundwork for subsequent investigations and assessments of the specific issues and questions raised by the decision-makers in the previous section.

C. FORMULATING AN ANALYSIS APPROACH

1. The General Analysis Approach

The next major activity within the Problem Formulation and Control module is that of formulating an analysis approach. In general, the approach that is recommended here is to split the SuperCINC problem into two separate problems: one assessing near-term solution alternatives and one addressing solutions out in the 2000 to 2010 time-frame. For the remainder of this thesis, only the far-term SuperCINC problem will be directly examined. The general analysis structure suggested for use in assessing these two problems is that of the Modular Analysis Process (as developed earlier in this thesis).

The remaining activities suggested by the MAP when formulating the analysis approach are those of specifying the initial analysis assumptions, selecting the analysis perspectives to be used throughout the analysis, and finally, previewing and scoping the remaining modules within the MAP. The following subsections will address each of these activities.

2. Assumptions about the SuperCINC Problem

The following is a list of the major assumptions associated with the SuperCINC problem:

1. Strategic Defense Initiateve (SDI) systems will be operationally deployed by both the United States and the Soviet Union. Both the U.S. and the Soviet SDI systems will have a capability to neutralize Intercontinental Ballistic Missile (ICBM) systems as well as Sea Launched Ballistic Missile (SLBM) systems. These SDI systems will be able to attack the ICBMs and SLBMs in their boost, mid-course, and terminal phases of trajectory. The SDI systems will use man-in-the-loop decisions for defensive systems' release authority as well as for selecting various alternative SDI weapons allocations. These SDI systems will only have a very limited capability against cruise missiles (e.g., in the terminal phases) and will be very restricted on the numbers and types of friendly targetted positions that can be protected. These protected positions are assumed to be variable based on inputs from the SDI system battle managers. The sensory information available to the SDI system battle management systems will also be made available to the strategic offensive forces and other government users.

2. The current alliance structures will still exist in the 2000 to 2010 time-frame.

3. The current regional tensions' associations between opposed nations, nation-groups, and national factions will still exist. The current political and ideological orientatons will remain unchanged world-wide.

4. The United States will have deployed a mobile ICBM system.

5. The United States will not have a well developed civil defense program. Essentially, it will have remained unchanged from its current status. The Soviet Union and its allies will continue to have an extensive capability to protect their population through civil defense programs.

6. The current unified and specified command structure will remain essentially unchanged. Hence, the following two existing specified commands would be considered in the analysis: the Strategic Air Command (SAC) and the Forces Command. The following eight unified commands would be in existence in the time-frame considered in the analysis: The European Command (EUCOM), the Pacific Command (PACOM), the Atlantic Command (LANTCOM), the Southern Command (SOUTHCOM), the Transportation Command, the Space Command, the Special Operations Command, and the Central Command (CENTCOM).

3. Selecting the Analysis Perspectives

This step in the formulation of an analysis approach specifies which analysis perspectives will be used in the analysis process and gives an initial indication of how many analysis project resources will be dedicated to each perspective. Given the nature of the SuperCINC problem, all three perspectives, as described in Chapter III, will need to be addressed. For example, the personal perspective will prove helpful in assessing the role of the key national leadership within the framework of the SuperCINC system. This perspective will also prove useful in assessing options between various candidates in the role of the SuperCINC and how the perspective would prove valuable in assessing the impacts of actions and attitudes likely to be taken by personnel because of personal concerns associated with family, survival, ethics, etcetera during the course of selected scenarios. Approximately ten percent of the analysis resources would initially be allocated to examining this perspective.

The organizational perspective would be the most important perspective for analysis within the SuperCINC problem. Numerous organizational issues exist, such as those associated with the politics of possibly consolidating power in the form of operational command authority within a single organization. Other examples of organizational issues would be assessing what the various roles, activities, and doctrines should be between the candidate SuperCINC organizations and the CINCs, the Services, the OSD, the JCS, the forces, other governmental agencies, the public, allies, neutrals, and enemies. All of these trade-off analyses would be assessed within the context of the various SuperCINC problem scenarios. Approximately fifty percent of the analysis resources would be initially dedicated to the analysis of the organizational perspective.

The last perspective to be considered is the technical perspective. This perspective would be concerned with issues associated with how to assess the various alternatives for C3 support systems for the SuperCINC system. Specific issues to consider here would include how the various alternative C3 systems limit or facilitate the organizational alternatives and their associated doctrines. The contribution of various C3 system alternatives to the mission accomplishment of the SuperCINC system would be important to assess. The remaining forty percent of the analytic resources would be initially dedicated to these issues.

4. Previewing and Scoping the Remaining MAP Modules

The last major activity in formulating the analysis approach involves previewing and scoping the remaining modules in the MAP. Selected modules will be briefly addressed in the following paragraphs.

a. Previewing the Desired States Module

The next module in the MAP involves the formulating of the desired states. Chapter III of this thesis showed that these desired states were divided into three broad categories: capability objectives, implementation objectives, and political objectives.

The primary capability objectives of concern within the SuperCINC problem would fall into seven general areas, namely, deterrence, escalation control, battle management, damage limitation, reconstitution, negotiation, and conflict termination. The first capability objective would specify the desired states associated with maintaining a viable deterrent against selected possible enemies. An example of this form of objective might be that the SuperCINC system should be able to effectively orchestrate attacks against an enemy's leadership for up to a year after an initial major nuclear exchange, thus decreasing the likelihood of the enemy leadership ever initiating the conflict. Capability objectives for escalation control and conflict termination could be developed along similar lines. It is important to note that these capability objectives will be assessed by effectiveness measures to be developed later within the MAP.

Numerous implementation and political objectives for the SuperCINC system could be developed based on the criteria developed in Chapter III of this thesis. Creating several objective levels within certain desired states, such as differing life-cycle cost levels, would facilitate the consideration of a broader range of alternatives at the onset of the analysis. It is suggested that implementation and political objectives identified at the onset of an analysis not be set too rigidly in order to facilitate the alternatives development process.

b. Previewing the Formulating Solution Alternatives Module

Previewing this module involves identifying what the initial scope of activities should be when performing this module. As a minimum, the following activities should be performed:

1. A survey should be conducted of the enemy command structures to see if there are any lessons to be learned or weaknesses to exploit.
2. Examine current CINC and allied command systems to determine their strengths and weaknesses.

3. Examine the national level command systems to determine their strengths and weaknesses.
4. Finally, select a team of analysts with interparadigmatic and interdisciplinary backgrounds to help generate alternatives.

c. Previewing the Formulating the Scenarios Module

When previewing the Formulating the Scenarios module for the SuperCINC problem, the following activities may be performed:

1. Identify where the information sources reside that project what the threats will be in the future. The sources can be documents or people.
2. List questions that may need to be answered during the development of a scenario.
3. Prepare at least one general scenario that highlights the key issues of interest within the SuperCINC problem.

The following three figures overview two candidate scenarios for examining the SuperCINC problem. The first of these scenarios examines a case where the superpowers gradually build up to a generated posture before the outbreak of hostilities. The second scenario examines a "bolt out of the blue" scenario where the Soviets initiate a surprise attack. This second scenario is designed to illustrate sensitivities within the various alternatives. These scenarios were adapted from an article written by Jack Anderson in the Washington Post newspaper [Ref. 31: p. D13].

D. CHAPTER SUMMARY

This chapter has applied a few of the modules of the Modular Analysis Process as developed in the first three Chapters of this thesis. Specifically, a problem posed in a memorandum for the Deputy Assistant Secretary of Defense for C3 was examined. This chapter primarily helped to identify what some of the major issues were with regards to this SuperCINC problem as well as suggesting some scenarios that could help with the analysis of these issues.

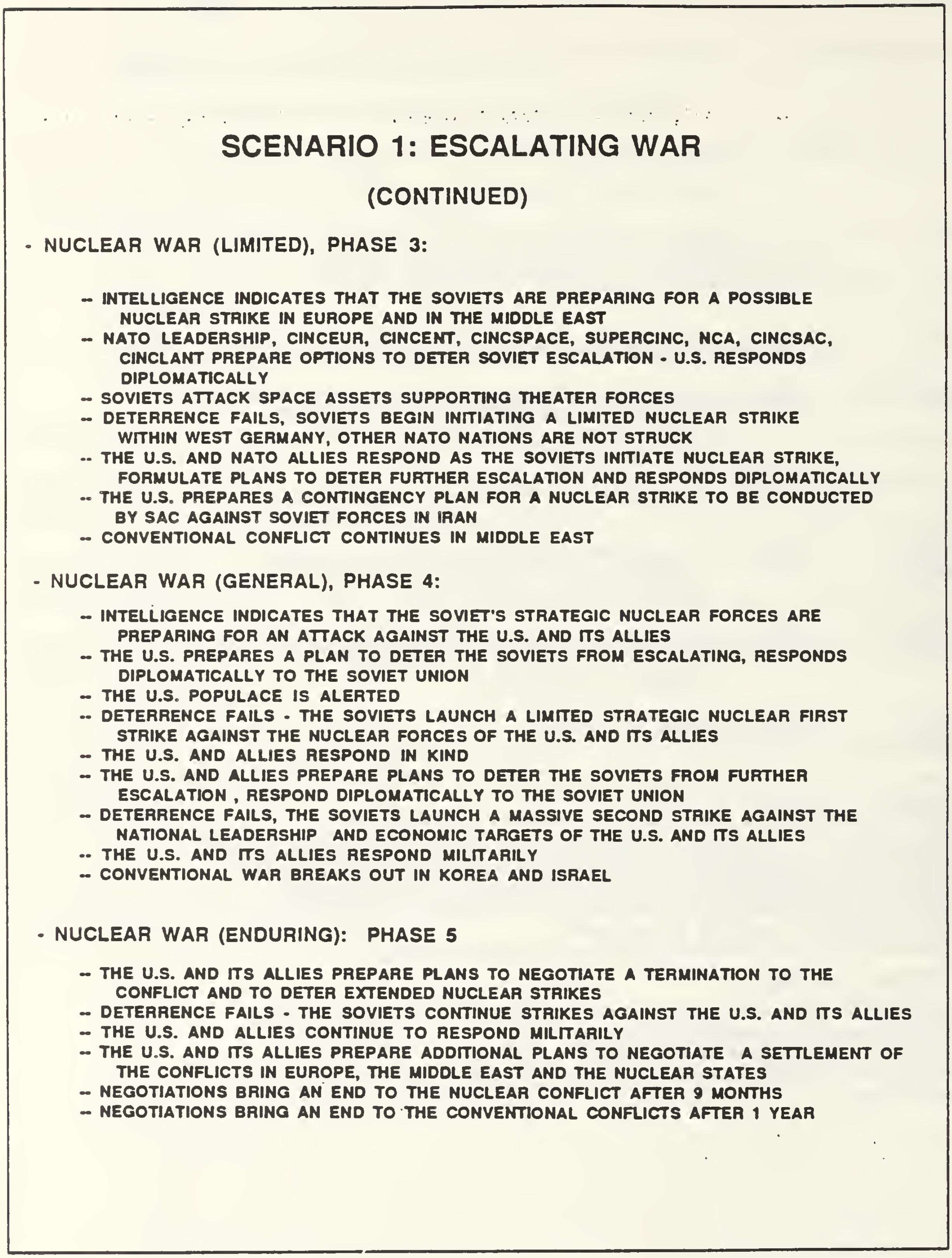
SCENARIO 1: ESCALATING WAR

- MAJOR U.S. & ALLIED SCENARIO PARTICIPANTS

-- CONVENTIONAL	PHASE 1:	NCA, SUPER COMMAND, CINCENT, CINCEUR, CINCLANT TRANSPORTATION COMMAND, SPECIAL OPERATIONS COMMAND, FORCES COMMAND, NATO, ISRAEL, SAUDI ARABIA, EGYPT
	PHASE 2:	SAME AS ABOVE, BUT INCLUDE PACOM, KOREA
-- NUCLEAR (LIMITED)	PHASE 3:	NCA, SUPER COMMAND, CINCENT, SAC, EUCOM, LANTCOM, NATO -- CONVENTIONAL WAR ONGOING, PHASE 2 PARTICIPANTS
-- NUCLEAR (GENERAL)	PHASE 4:	SAME AS PHASE 3, BUT ADD SPACE COMMAND, PACOM NORAD, CONVENTIONAL WAR ONGOING, PHASE 2 PARTICIPANTS
-- NUCLEAR (ENDURING)	PHASE 5:	SAME AS PHASE 4

- CONVENTIONAL, PHASE 1:
  - -- TENSIONS RISE IN MIDDLE EAST AS OVER 20 SOVIET DIVISIONS MOVE TOWARD IRAN
  - -- CINCCENT REQUESTS MOBILIZATION SUPPORT (AIR AND SEA), DEPLOYS FORCES
  - -- TENSIONS RISE IN EUROPE OVER PLANNED LARGE-SCALE SOVIET EXERCISE,
  - -- CINCEUR REQUESTS MOBILIZATION SUPPORT AS DETERRENT, FORCES DEPLOY
  - -- SOVIETS INVADE IRAN - - OVER 20 DIVISIONS
  - -- SOVIET & US FORCES ENGAGE IN CONVENTIONAL CONFLICT IN IRAN
- CONVENTIONAL, PHASE 2:
  - -- SOVIET EXERCISE IN EUROPE TURNS INTO INVASION OF W. GERMANY, CONFLICT ENSUES BETWEEN NATO AND SOVIET FORCES
  - -- NORTH KOREA PREPARES TO INVADE SOUTH KOREA
  - -- SYRIA AND SYMPATHETIC ARAB STATES AND FACTIONS MOBILIZE FOR ATTACK AGAINST ISRAEL

Figure 4.2 Escalating War Scenario - Part I



SCENARIO 1: ESCALATING WAR

(CONTINUED)

- NUCLEAR WAR (LIMITED), PHASE 3:
  - INTELLIGENCE INDICATES THAT THE SOVIETS ARE PREPARING FOR A POSSIBLE NUCLEAR STRIKE IN EUROPE AND IN THE MIDDLE EAST
  - NATO LEADERSHIP, CINCEUR, CINCENT, CINCSPACE, SUPERCINC, NCA, CINCSAC, CINCLANT PREPARE OPTIONS TO DETER SOVIET ESCALATION - U.S. RESPONDS DIPLOMATICALLY
  - SOVIETS ATTACK SPACE ASSETS SUPPORTING THEATER FORCES
  - DETERRENCE FAILS, SOVIETS BEGIN INITIATING A LIMITED NUCLEAR STRIKE WITHIN WEST GERMANY, OTHER NATO NATIONS ARE NOT STRUCK
  - THE U.S. AND NATO ALLIES RESPOND AS THE SOVIETS INITIATE NUCLEAR STRIKE, FORMULATE PLANS TO DETER FURTHER ESCALATION AND RESPONDS DIPLOMATICALLY
  - THE U.S. PREPARES A CONTINGENCY PLAN FOR A NUCLEAR STRIKE TO BE CONDUCTED BY SAC AGAINST SOVIET FORCES IN IRAN
  - CONVENTIONAL CONFLICT CONTINUES IN MIDDLE EAST

- NUCLEAR WAR (GENERAL), PHASE 4:
  - INTELLIGENCE INDICATES THAT THE SOVIET'S STRATEGIC NUCLEAR FORCES ARE PREPARING FOR AN ATTACK AGAINST THE U.S. AND ITS ALLIES
  - THE U.S. PREPARES A PLAN TO DETER THE SOVIETS FROM ESCALATING, RESPONDS DIPLOMATICALLY TO THE SOVIET UNION
  - THE U.S. POPULACE IS ALERTED
  - DETERRENCE FAILS - THE SOVIETS LAUNCH A LIMITED STRATEGIC NUCLEAR FIRST STRIKE AGAINST THE NUCLEAR FORCES OF THE U.S. AND ITS ALLIES
  - THE U.S. AND ALLIES RESPOND IN KIND
  - THE U.S. AND ALLIES PREPARE PLANS TO DETER THE SOVIETS FROM FURTHER ESCALATION , RESPOND DIPLOMATICALLY TO THE SOVIET UNION
  - DETERRENCE FAILS, THE SOVIETS LAUNCH A MASSIVE SECOND STRIKE AGAINST THE NATIONAL LEADERSHIP AND ECONOMIC TARGETS OF THE U.S. AND ITS ALLIES
  - THE U.S. AND ITS ALLIES RESPOND MILITARILY
  - CONVENTIONAL WAR BREAKS OUT IN KOREA AND ISRAEL

- NUCLEAR WAR (ENDURING): PHASE 5
  - THE U.S. AND ITS ALLIES PREPARE PLANS TO NEGOTIATE A TERMINATION TO THE CONFLICT AND TO DETER EXTENDED NUCLEAR STRIKES
  - DETERRENCE FAILS - THE SOVIETS CONTINUE STRIKES AGAINST THE U.S. AND ITS ALLIES
  - THE U.S. AND ALLIES CONTINUE TO RESPOND MILITARILY
  - THE U.S. AND ITS ALLIES PREPARE ADDITIONAL PLANS TO NEGOTIATE A SETTLEMENT OF THE CONFLICTS IN EUROPE, THE MIDDLE EAST AND THE NUCLEAR STATES
  - NEGOTIATIONS BRING AN END TO THE NUCLEAR CONFLICT AFTER 9 MONTHS
  - NEGOTIATIONS BRING AN END TO THE CONVENTIONAL CONFLICTS AFTER 1 YEAR

Figure 4.3 Escalating War Scenario - Part II

SCENARIO 2: SURPRISE ATTACK

- MAJOR U.S. & ALLIED SCENARIO PARTICIPANTS

– MOBILIZATION	PHASE I:	NCA, SUPER COMMAND, CINCENT, CINCEUR, CINCLANT TRANSPORTATION COMMAND, SPECIAL OPERATIONS COMMAND, FORCES COMMAND, NATO, ISRAEL, SAUDI ARABIA, EGYPT
-- GENERAL NUCLEAR WAR	PHASE 2:	SAME AS ABOVE, BUT INCLUDE PACOM, KOREA, SPACE COMMAND, NORAD, AND FEMA
-- ENDURING WAR	PHASE 3:	SAME AS PHASE 2

- MOBILIZATION, PHASE 1
  - -- TENSIONS RISE IN MIDDLE EAST AS THE SOVIETS CONDUCT A LARGE-SCALE EXERCISE NEAR THE BORDER OF IRAN
  - -- CINCCENT REQUESTS MOBILIZATION SUPPORT (AIR AND SEA), DEPLOYS FORCES FOR A CONCURRENT EXERCISE IN EGYPT AND SAUDI ARABIA -- TO ACT AS A DETERRENT TO ANY SOVIET INVASION OF IRAN
  - -- TENSIONS RISE IN EUROPE OVER PLANNED LARGE-SCALE SOVIET EXERCISE
  - -- CINCEUR REQUESTS MOBILIZATION SUPPORT AS DETERRENT, FORCES DEPLOY FOR A CONCURRENT U.S. AND ALLIED EXERCISE
- GENERAL NUCLEAR AND CONVENTIONAL WAR, PHASE 2:
  - -- SOVIETS LAUNCH A SURPRISE MASSIVE NUCLEAR ATTACK AGAINST THE U.S. NUCLEAR FORCES AND AGAINST THE CONVENTIONAL U.S. FORCES AT THEIR MOBILIZATION STAGING AREAS WITHIN THE U.S.
  - -- CONCURRENTLY, SOVIET EXERCISE IN EUROPE TURNS INTO INVASION OF W. GERMANY, CONVENTIONAL CONFLICT ENSUES BETWEEN NATO AND SOVIET FORCES AFTER A PRECURSORY NUCLEAR ATTACK AGAINST NATO FORCES AND C3I
  - -- SOVIETS INVADE IRAN, ENGAGE REGIONAL U.S. FORCES WITH CHEMICAL AND NUCLEAR WEAPONS
  - -- NORTH KOREA PREPARES TO INVADE SOUTH KOREA
  - -- SYRIA AND SYMPATHETIC ARAB STATES AND FACTIONS MOBILIZE FOR ATTACK AGAINST ISRAEL
  - -- THE U.S. AND ITS ALLIES RESPOND MILITARILY WITH CONVENTIONAL AND NUCLEAR ATTACKS AGAINST THE SOVIET HOMELAND, THE WARSAW PACT, AND SOVIET MIDDLE EASTERN FORCES
- ENDURING WAR, PHASE 3
  - -- THE U.S. PREPARES PLANS TO DETER THE SOVIET UNION FROM FURTHER NUCLEAR ATTACKS AGAINST THE CONTINENTAL U.S. AND CANADA, AS WELL AS IN EUROPE AND IN THE MIDDLE EAST - RESPONDS TO THE SOVIET UNION DIPLOMATICALLY
  - -- DETERRENCE FAILS - THE SOVIETS CONTINUE STRIKES AGAINST THE U.S. AND ITS ALLIES AND INVADE OTHER NATO NATIONS
  - -- THE U.S. AND ITS ALLIES PREPARE ADDDITIONAL PLANS TO NEGOTIATE A SETTELMENT OF THE CONFLICTS IN EUROPE, THE MIDDLE EAST AND THE NUCLEAR STATES
  - -- NEGOTIATIONS BRING AN END TO THE NUCLEAR CONFLICT AFTER 6 MONTHS
  - -- NEGOTIATIONS BRING AN END TO THE CONVENTIONAL CONFLICT AFTER 1 YEAR

Figure 4.4 Surprise Attack Scenario

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